Lloyd's Register

Rules and Regulations for the Classification of Ships, July 2007

Notice No. 5

Effective Date of Latest Amendments:

See page 1

Issue date: June 2008

RULES AND REGULATIONS FOR THE CLASSIFICATION OF SHIPS, *July 2007*

Notice No. 5

This Notice contains amendments within the following Sections of the *Rules and Regulations for the Classification of Ships, July 2007.* The amendments are effective on the dates shown:

Part	*Chapter*	*Section*	*Effective date*
3	2	2	1 March 2008
3	9	6, 7, 8	1 March 2008
3	9	9	Corrigenda
3	9	10, 11, 12, 13	1 March 2008
5	9	1, 2, 3, 4	1 March 2008
8	1	Whole Chapter	1 March 2008
8	2	Whole Chapter	1 March 2008

It will be noted that the amendments also include corrigenda, which are effective from the date of this Notice.

The *Rules and Regulations for the Classification of Ships, July 2007* are to be read in conjunction with this Notice No. 5. The status of the Rules is now:

Rules for Ships	Effective date:	July 2007
Notice No. 1	Effective dates:	1 August 2007, 1 January 2008 & Corrigenda
Notice No. 2	Effective dates:	1 July 2007, 1 October 2007, 1 January 2008 & 1 July 2008
Notice No. 3	Effective dates:	1 January 2009, 1 March 2008, & 1 July 2008 & Corrigenda
Notice No. 4	Effective dates:	1 January 2008, 1 July 2008 & Corrigenda
Notice No. 5	Effective dates:	1 March 2008 & Corrigenda

Part 3, Chapter 2
Materials

Effective date 1 March 2008

■ *Section 2* **Fracture control**

~~2.3 Grades of steel for ice-breaking ships~~ designed to operate in low ambient temperatures

2.3.1 These requirements are intended for ships strengthened in accordance with the requirements stated in Ch 9,8 and designed to operate for long periods in low air temperatures.

2.3.2 The grade of steel to be used is related to the anticipated operating temperature, T_0, degree of ice induced dynamic loading and the thickness of material. In no case should the grade of steel be less than that required by 2.1 or 2.2.

2.3.3 In order to establish the anticipated operating temperature, T_0, for a given structural member, it is assumed that the minimum design air temperature, T, for ships designed to operate in Arctic or Antarctic conditions, is not lower than –45°C and should not be taken as higher than –35°C. It is the responsibility of the Owner to specify the design air temperature T. Where reliable environment records for contemplated operational areas exist, the minimum design air temperature can be obtained after the exclusion of all recorded values having a probability of occurrence of less than 3 per cent. If T is lower than –45°C then the steel grades to be used will be specially considered.

2.3.4 The operating temperature T_0 relevant for the selection of steel grades is given in Table 2.2.5.

2.3.5 Steel grades for plating forming the outer shell and deck boundaries are obtained from the figures specified in Table 2.2.5. The strakes of shell plating to which the bilge keels or ground bars are attached are to be made of Grade D steel over the forward 0,5L but may be of Grade B steel elsewhere.

2.3.6 In general, longitudinal frames and longitudinal bulkhead strakes attached to deck and shell and outboard strakes of horizontal stringers are to be of the same steel grade as the hull envelope plating to which they are connected, but the grade may be adjusted to take account of difference in thickness.

2.3.7 The outer strake of web plating of web frames is to be constructed of material of the same steel grade as the shell plating to which they are attached, but the grade may be adjusted to take account of difference in thickness.

2.3.8 The steel grade of transverse side frames and the strakes of transverse bulkhead plating directly attached to the shell in Region A, *see* Table 2.2.5, are to be determined from Fig. 2.2.2 in conjunction with an operating temperature of (T + 10)°C.

2.3.9 Steel grades for rudder horn, stern frame and stem (including the adjacent strake of shell plating), are given in ~~Table 2.2.6. The steel grades of internal members attached to these items are to be of the same grade (or equivalent) with~~ due account taken of difference in thickness

Table 2.2.5 Steel grades and operating temperatures for ships intended to navigate in Arctic and Antarctic conditions

Region	Position	Operating temp. T_0°C	Steel grade Fig. No.
A	Region between a line set at a distance 0,1D or 2 m (whichever is less) below the Ice Light Waterline and a line set the same distance above the Ice Load Waterline:		
	Forward of 0,3L from the F.P. Abaft 0,3L from the F.P.	T + 10 T + 10	2.2.1 2.2.2
B	Region between the keel and a line set at the lesser of 0,1D or 2 m below the Ice Light Waterline		
	Forward of 0,3L from the F.P. Permanently immersed parts of the welded stern frame	T + 20 T + 20	2.2.1 2.2.2
C	Exposed portions of side shell, main deck, stem and stern, excluding coamings, protected positions and forecastle sides:		
	Forward of 0,3L from the F.P. Abaft of 0,3L from the F.P.	T, *see* Note T, *see* Note	2.2.1 2.2.2
D	Main deck protected from open environment, i.e. within accommodation block or forecastle, etc., but excluding a 1 m wide strip adjacent to boundaries which are to be treated as exposed:		
	Permanently heated spaces Permanently unheated spaces	0 –15	2.2.2 2.2.2
E	Deck coamings, hatch covers, crane pedestals	T + 5	2.2.2
F	External bulkheads of accommodation block (the lowest strake is not to be less than Grade D), and forecastle sides	T + 20 but not greater than –10ºC	2.2.2
G	Forecastle deck	T + 10, *see* Note	2.2.2
H	All other permanently immersed structure	—	Normal Rule Requirement

NOTE
For ships intended to operate only during the summer period and to be laid up in winter the operating temperature T_0 may be taken ~~as T + 20 but need not be taken lower than –18°C.~~

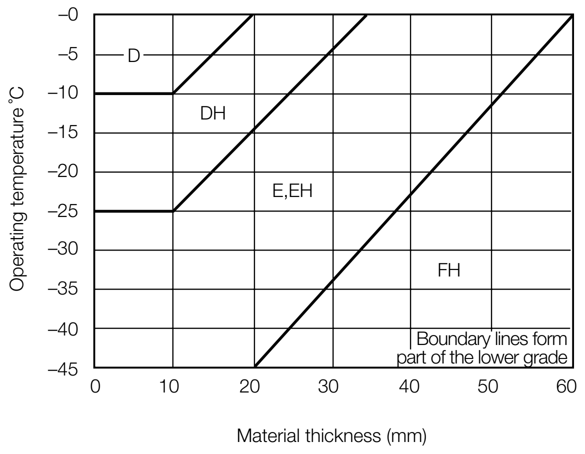


Fig. 2.2.1
Steel grade (Forward of 0,3*L* from the F.P.)

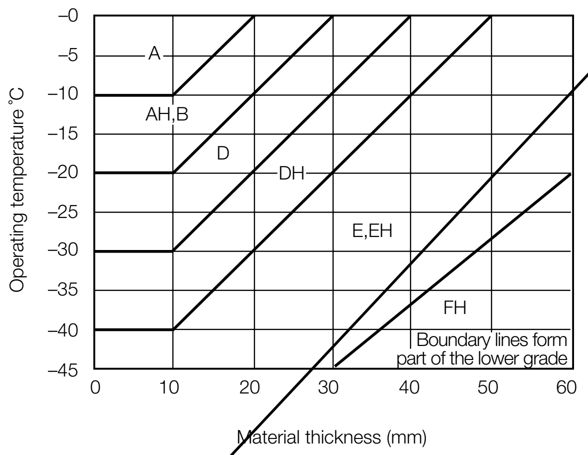


Fig. 2.2.2 Steel grade (Remaining positions)

Table 2.2.6 Steel grades for rudder horn, stern frame and stem for ships intended to navigate in Arctic or Antarctic conditions

Item	Condition	Construction	Steel grade(2)(3)	
			f < 25(1)	f ≥ 25(1)
Rudder horn	Fully immersed	Cast steel	Carbon manganese steel Grade 400	Carbon manganese steel Grade 400
		Fabricated	Grade EH	Grade EH
	Periodically immersed or exposed	Cast steel	Carbon manganese steel Grade 460	$2\frac{1}{4}$ Ni steel or equivalent
		Fabricated	Grade FH	$1\frac{1}{2}$ Ni steel or equivalent
Stern frame	Fully immersed	Cast steel	Normal Rule requirement	Normal Rule requirement
		Fabricated	Table 2.2.5 Region B	Table 2.2.5 Region B
	Periodically immersed or exposed	Cast steel	Carbon manganese steel Grade 400	Carbon manganese steel Grade 460
		Fabricated	Table 2.2.5 Region C	Grade FH
Stem including adjacent strake of shell plating	Fully immersed	Fabricated	Table 2.2.5 Region B	Table 2.2.5 Region B
		Cast steel	Carbon manganese steel Grade 400	Carbon manganese steel Grade 400
	Periodically immersed or exposed	Fabricated	Table 2.2.5 Region C	Table 2.2.5 Region C
		Cast steel	$2\frac{1}{4}$ Ni steel	$2\frac{1}{4}$ Ni steel

NOTES

1. $f = \sqrt{P_o \Delta} \times 10^{-3} \left(= 0,858 \sqrt{H_o \Delta} \times 10^{-3}\right)$

   where P_o (H_o) is the maximum propulsion shaft power for which the machinery is classed
   Δ is displacement, in tonnes, at Ice Load Waterline or Deepest Ice Operation Waterline when floating in water of relative density of 1,0.

2. For cast steel, *see* Pt 2, Ch 4,7.
3. For C–Mn LT60 and Ni plates, *see* Pt 2, Ch 3,6.

Part 3, Chapter 9
Special Features

Effective date 1 March 2008

■ ~~*Section 6*~~
Strengthening requirements for navigation in ice – Application of requirements

6.1 Additional strengthening

6.1.1 Where additional strengthening is fitted in accordance with the requirements given in Sections 7 and 8, an appropriate special features notation will be assigned. It is the responsibility of the Owner to determine which notation is most suitable for his requirements. For material requirements, *see* Ch 2,2. For machinery requirements, *see* Pt 5, Ch 9.

6.1.2 Where a special features notation is desired, the ship is to comply with the requirements of the applicable Sections, in addition to those for sea-going service, so far as they are applicable.

6.1.3 Ships that comply with the requirements of the Finnish Swedish Ice Class Rules in force at the time of contract and Section 7, for Ice Class **IA Super, IA, IB** and **IC** may be assigned the corresponding notations Ice Class **1AS FS,** Ice Class **1A FS,** Ice Class **1B FS** or Ice Class **1C FS.** The Finnish Swedish Ice Class Rules may be obtained from the following website:
www.fma.fi

6.1.4 The requirements for **Ice Class 1D** are for ships intended to navigate in light first year ice conditions. The requirements for strengthening the forward region, the rudder and steering arrangements for **Ice Class 1C FS** are applicable.

6.1.5 The requirements for Ice Class **IE** are for offshore supply ships, as defined in Pt 4, Ch 4, and are intended to navigate in very light first-year ice conditions, such as in brash ice and small ice pieces. The requirements of Section 9 are to be complied with.

6.1.6 For ships where the ice class notation Ice Class **1AS FS(+),** Ice Class **1A FS(+),** Ice Class **1B FS(+)** or Ice Class **1C FS(+)** is requested, the requirements of the Finnish Swedish Ice Class Rules in force at the time of contract, and Section 7, and Pt 5, Ch 9,4 are to be complied with.

6.1.7 The requirements for strengthening for navigation in ice, as given in Section 8, are intended for ships operating in multi-year ice in Arctic or Antarctic ice conditions under their own power.

6.2 Geographical zones

6.2.1 Ships intending to navigate in the Canadian Arctic must comply with the *Canadian Arctic Shipping Pollution Prevention Regulations* established by the Consolidated ~~Regulations of Canada, 1978, Chapter 353, in respect of which Lloyd's Register (hereinafter referred to as 'LR') is~~ authorized to issue Arctic Pollution Prevention Certificates.

6.2.2 The Canadian Arctic areas have been divided into zones relative to the severity of the ice conditions experienced and, in addition to geographic boundaries, each zone has seasonal limits affecting the necessary ice class notation required to permit operations at a particular time of year. It is the responsibility of the Owner to determine which notation is most suitable for his requirements.

6.2.3 The Canadian Authorities recognize that in the period November 6 to July 31 and any extension to that period declared by the Canadian Coast Guard, oil and bulk chemical tankers which qualify for Canadian Type A, B, C and D as indicated in Table 9.6.1 are suitable for operating in designated ice control zones within Canadian waters, off the east coast of Canada south of 60° north latitude. For all Type E tankers operating in this zone during the specified period, the Canadian Authorities will require either additional hull strength in way of the forward wing cargo tanks port and starboard, or the level of oil or chemical in these tanks to be not higher than one metre below the waterline of the ship in her condition of transit. Where the latter arrangement is adopted, the effect on longitudinal strength is to be considered.

Table 9.6.1 Canadian Types

Canadian Type	Lloyd's Register Ice Class Notation	
Type A	100A1	Ice Class 1AS FS
Type B	100A1	Ice Class 1A FS
Type C	100A1	Ice Class 1B FS
Type D	100A1	Ice Class 1C FS and 1D
Type E	100A1	

6.3 Icebreakers

6.3.1 Sea-going ships specially designed for icebreaking duties will be assigned the ship type notation 'Icebreaker' in addition to the special features notation appropriate to the degree of ice strengthening provided.

■ *Section 7*
Strengthening requirements for navigation in first-year ice conditions

7.1 General

7.1.1 In addition to the requirements of the Finnish Swedish Ice Class Rules,the following sections are to be complied with for **Ice Class 1AS FS**, **Ice Class 1A FS**, **Ice Class 1B FS**, **Ice Class 1C FS** and **Ice Class 1D** where applicable. Alternative arrangements to attain similar performance will be specially considered.

7.1.2 The ballast capacity of the ship is to be sufficient to give adequate propeller immersion in all ice navigating conditions without trimming the ship in such a manner that the actual waterline at the bow is below the ice light waterline. Ballast tanks situated above the ice light waterline and adjacent to the shell, which are intended to be used in ice navigating conditions, are to be provided with heating pipes.

7.1.3 These Rules are formulated for both transverse and longitudinal framing systems but it is recommended that, whenever practicable, transverse framing is selected.

7.1.4 These Rules assume that when approaching ice infested waters, the ship's speed will be reduced appropriately. The vertical extent of ice strengthening for ships intended to operate at speeds exceeding 15 knots in areas containing isolated ice floes will be specially considered.

7.1.5 An icebreaking ship is to have a hull form at the fore end adapted to break ice effectively. It is recommended that bulbous bows are not fitted to Ice Class 1AS ships.

7.1.6 The stern of an icebreaking ship is to have a form such that broken ice is effectively displaced.

7.1.7 Where it is desired to make provision for short tow operations, the bow area is to be suitably reinforced. Similarly, icebreakers may require local reinforcement in way of the stern fork.

7.1.8 The vertical extent of the ice strengthening is related to the ice light and ice load waterlines, which are defined in 7.3. The maximum and minimum Ice Class draughts at both the fore and aft ends will be stated on the Class Certificate. In addition, the minimum engine output, *see* Pt 5, Ch 9, will be stated on the Class Certificate.

7.2 Definitions

7.2.1 The Ice Load Waterline corresponds to the Fresh Water Summer Loadline. Where specially requested and where permitted by the appropriate National Administration, an Ice Load Waterline may be specified which differs from the foregoing, but corresponds to the deepest condition in which the ship is expected to navigate in ice.

7.2.2 The Ice Light Waterline is that corresponding to the lightest condition in which the ship is expected to navigate ice.

7.2.3 The Ice Load Waterline and the Ice Light Waterline are to be indicated on the plans. For navigation in certain geographical areas, the relevant National Authority may require the maximum Ice Class draught to be marked on the ship in a specified manner.

7.2.4 **Displacement** Δ is the displacement, in tonnes, at the Ice Load Waterline when floating in water having a relative density of 1,0.

7.2.5 **Shaft power**, P_0 (H_0), is the maximum propulsion shaft power, in kW (shp), for which the machinery is to be classed.

7.3 Framing – General requirements

7.3.1 Where a frame intersects a boundary between two of the hull regions the scantling requirements applicable will be those for the forward region if the forward midship boundary is intersected or for the midship region if the aft midship boundary is intersected.

7.3.2 The effective weld area attaching ice frames to primary members is not to be less than the shear area for the frames.

7.4 Primary longitudinal members supporting transverse ice framing

7.4.1 The webs of primary longitudinal members supporting transverse ice frames are to be stiffened and connected to the main or intermediate frames so that the distance, r, between such stiffening is not to be greater than given according to the following formula:

$$r = \sqrt{\frac{291 t^3}{\alpha_o \gamma^2}} \text{ mm}$$

where

t = thickness, in mm, of the primary longitudinal member adjacent to the shell plating

α_o = longitudinal distribution factor as given in Table 9.7.1

(a) Forward region

$$\gamma = 0{,}653 + 3{,}217 \sqrt{P_0 \Delta} \times 10^{-5}$$

$$(\gamma = 0{,}653 + 2{,}76 \sqrt{H_0 \Delta} \times 10^{-5}), \text{ or}$$

$$\gamma = 0{,}876 + 9{,}908 \sqrt{P_0 \Delta} \times 10^{-6}$$

$$(\gamma = 0{,}876 + 8{,}5 \sqrt{H_0 \Delta} \times 10^{-6})$$

or γ = 1,0 whichever is the least

where P_0 (H_0) and Δ are as defined in 7.2.

(b) Midship and aft regions

$$\gamma = 0{,}653 + 9{,}908 \sqrt{P_0 \Delta} \times 10^{-6}$$

$$(\gamma = 0{,}653 + 8{,}5 \sqrt{H_0 \Delta} \times 10^{-6})$$

or γ = 0,79, whichever is the lesser.

Table 9.7.1 Longitudinal distribution factor α_o

Ice Class	α_o		
	Forward	Midship	Aft
1AS FS	1,00	0,98	0,89
1A FS	0,87	0,75	0,64
1B FS	0,78	0,64	0,51
1C FS	0,68	0,53	0,37
1D	0,68	—	—

7.4.2 The minimum thickness of the web plating of longitudinal primary members is to comply with the requirements of Ch 10,4.

7.5 Stem

7.5.1 The stem is to be made of rolled, cast or forged steel or of shaped steel plates. A sharp edged stem, as shown in Fig. 9.7.1 improves the manoeuvrability of the ship in ice.

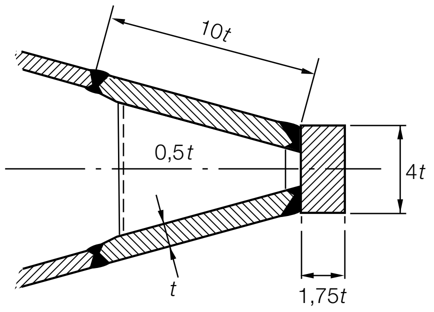


Fig. 9.7.1 A sharp edged stem

7.5.2 The section modulus of the stem in the fore and aft direction is not to be less than determined in accordance with the following formula:

$$Z = 1500\,(\alpha_o\,\gamma^2)^{3/2} \quad \text{cm}^3$$

where

α_o = longitudinal distribution factor for the forward region as given in Table 9.7.1

γ is defined in 7.5.2.

7.5.3 The dimensions of a welded stem constructed as shown in Fig. 9.7.1 are to be determined in accordance with the following formula:

$$t = 31\sqrt{\alpha_o\,\gamma^2} \quad \text{mm}$$

where

t = thickness of the side plates, in mm

7.5.4 In bulbous bow constructions, the extent of plating below the Ice Light Waterline should be such as to cover that part of the bulb forward of the vertical line originating at the intersection of the Ice Light Waterline and the stem contour at the centreline. A suitably tapered transition piece should be arranged between the reinforced stem plating and keel. However, in no case should the reinforced stem plating extend vertically below the Ice Light Waterline for less than 750 mm. The adjacent strake to the reinforced shaped stem plating of the bulb should be in accordance with the requirements for shell plating.

7.5.5 Where in the ice belt region the radius of the stem or bulb front plating is large, one or more vertical stiffeners are to be fitted in order to meet the section modulus requirement of 7.7.2. In addition, vertical ring stiffening will be required for the bulb.

7.5.6 The dimensions of the stem may be tapered to the requirements of Ch 5,3.3 at the upper deck. The connections of the shell plating to the stem are to be flush.

7.6 Stern

7.6.1 Where the screwshaft diameter exceeds the Rule diameter, the propeller post is to be correspondingly strengthened, *see* Ch 6,7.

7.7 Rudder and steering arrangements

7.7.1 Rudder scantlings, posts, rudder horns, solepieces, rudder stocks, steering engine and pintles are to be dimensioned in accordance with Chapters 6 and 13 as appropriate. The speed used in the calculations is to be the maximum service speed or that given in Table 9.7.3, whichever is the greater. When used in association with the speed given in Table 9.7.3, the hull form factor and the rudder profile coefficients are to be taken as 1,0.

Table 9.7.2 Longitudinal distribution factor α_p

Ice Class	α_p		
	Forward	Midship	Aft
1AS FS	1,00	0,95	0,85
1A FS	0,98	0,86	0,73
1B FS	0,93	0,71	0,57
1C FS	0,86	0,53	0,38
1D	0,86	—	—

Table 9.7.3 Minimum speed

Ice Class	Minimum speed, in knots
1AS FS	20
1A FS	18
1B FS	16
1C FS	14
1D	14

7.7.2 For double plate rudders, the minimum thickness of plating and horizontal and vertical webs in the main ice belt zone is to be determined as for shell plating in the aft region. For the horizontal and vertical webs the corrosion-abrasion increment, c, need not be added. For Ice Class 1D, the minimum thickness of plating and webs, of double plate rudders and the extent of application are to be determined as for those in Ice Class 1C FS.

7.7.3 Where an ice class notation is included in the class of a ship, the nozzle construction requirements, as defined in Table 13.3.1 in Chapter 13, are to be upgraded to include abrasion allowance as follows:

Ice Class	Thickness increment
1AS FS	5 mm
1A FS	4 mm
1B FS	3 mm
1C FS	2 mm
1D	2 mm

However, the thickness of the shroud plating is not to be less than the shell plating for the aft region taking frame spacing s in the formula as 500 mm.

7.7.4 The scantlings of the stock, pintles, gudgeon and solepiece associated with the nozzle are to be increased on the basis given in 7.7.1. However, the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as half the speed given in Table 9.7.3 or the actual astern speed, whichever is the greater.

7.7.5 Nozzles with articulated flaps will be subject to special consideration.

7.7.6 For the ice classes **1AS FS** and **1A FS** the rudder stock and the upper edge of the rudder shall be protected against ice pressure by an ice knife or equivalent means. The ice knife is to extend down to the ice light waterline; this requirement may be waived where this would lead to impracticable ice knifes, e.g. for ships with large draught variations.

7.7.7 For the ice classes **1AS FS** and **1A FS** due regard is to be paid to the excessive load caused by the rudder being forced out of the midship position when backing into an ice ridge. When vessels are intended to operate with significant time in astern operation, then the hull strength is to be based on the method used in the forward region, however due consideration may be given to the anticipated power in this mode of operation.

7.7.8 Relief valves for hydraulic pressure are to be effective, *see* Pt 5, Ch 19,3.3. The components of the rudder steering gear are to be able to withstand the yield torque of the rudder stock, *see* Pt 5, Ch 19,3.2.2. Rudder stoppers working on the rudder blade or rudder head are to be fitted.

■ *Section 8*
Strengthening requirements for navigation in multi-year ice conditions

8.1 Ice Class notations

8.1.1 Where the requirements of this Section are complied with, the ship will be eligible for the addition of the term ‘Icebreaking’ to the ship type notation, e.g. ‘Icebreaking Bulk Carrier’, ‘Icebreaking Tanker’, etc. In addition, one of the following special features notations will be assigned:

(a) **Ice Class AC1**: The requirements for the assignment of this class are intended for ships designed to navigate in Arctic or Antarctic ice conditions equivalent to unbroken ice with a thickness of 1,0 m.

(b) **Ice Class AC1,5**: The requirements for the assignment of this class are intended for ships designed to navigate in Arctic or Antarctic ice conditions equivalent to unbroken ice with a thickness of 1,5 m.

(c) **Ice Class AC2**: The requirements for the assignment of this class are intended for ships designed to navigate in Arctic or Antarctic ice conditions equivalent to unbroken ice with a thickness of 2,0 m.

(d) **Ice Class AC3**: The requirements for the assignment of this class are intended for ships designed to navigate in Arctic or Antarctic ice conditions equivalent to unbroken ice with a thickness of 3,0 m.

8.2 Application

8.2.1 The requirements of this Section are formulated on the assumption that ships having Ice Class AC notations will be longitudinally framed at the uppermost continuous deck and at the bottom. Alternative proposals will be specially considered.

8.2.2 The vertical extent of ice strengthening is related to the Ice Load Waterline or Deepest Ice Operating Waterline and the Ice Light Waterline as defined in 8.3. The maximum and minimum ice class draughts at both the fore and aft ends will be stated on the Class Certificate.

8.3 Definitions, *see* Fig. 9.8.1

8.3.1 The Ice Load Waterline corresponds to the Freshwater Load Line in summer as defined by the *1966 International Load Line Convention.*

8.3.2 A Deepest Ice Operating Waterline which differs from the Ice Load Waterline may be specified, where specially requested, and would correspond to the deepest condition in which the ship is expected to navigate in ice.

8.3.3 The Ice Light Waterline is that corresponding to the lightest condition in which the ship is expected to navigate in ice.

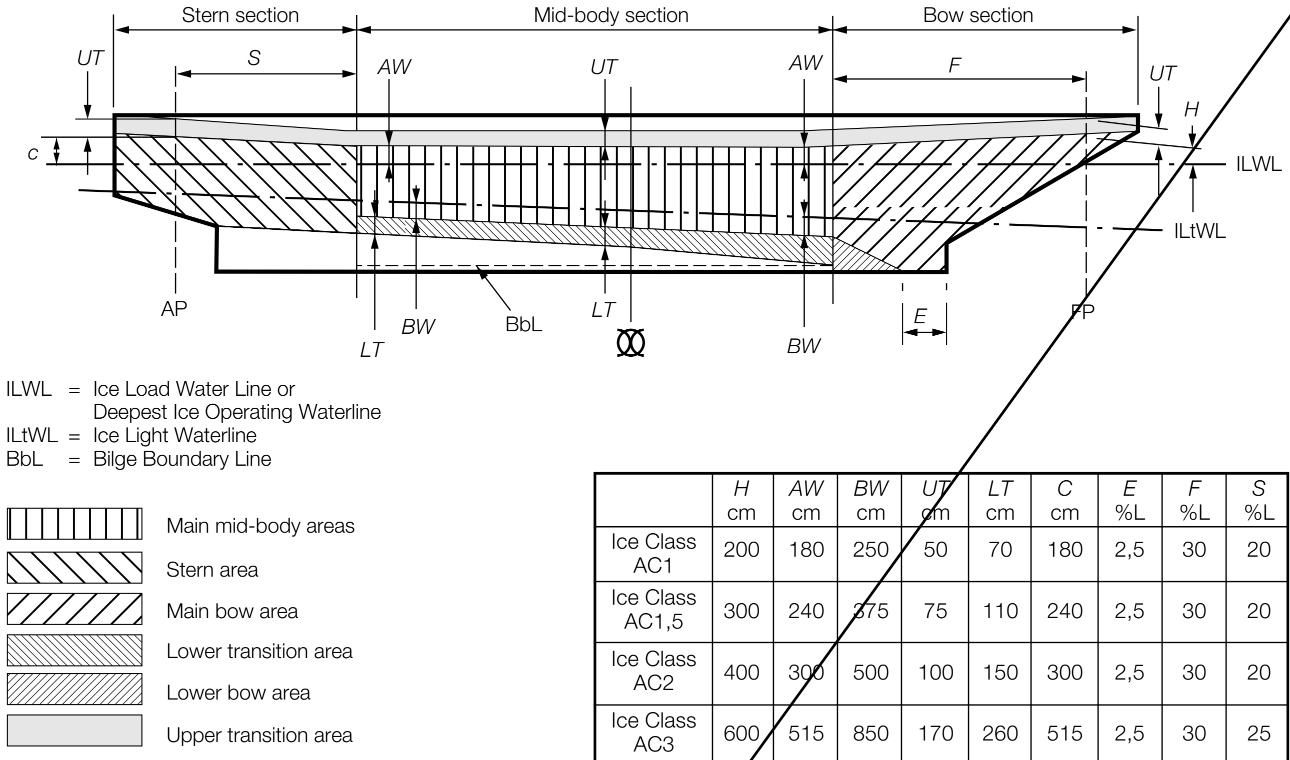
8.3.4 The Ice Load Waterline, the Deepest Ice Operating Waterline and the Ice Light Waterline should be indicated on the plans. For navigation in certain geographic areas, the relevant National Authority may require the maximum Ice Class draught to be marked on the ship in a specified manner.

8.3.5 For the purpose of defining the standard of ice strengthening required, which is dependent upon longitudinal and vertical position, the hull is divided longitudinally into three regions designated bow section, mid-body section and stern section. Each section is further subdivided in its depth so that the bow section contains the lower bow area, main bow area and that part of the upper transition area in way, the mid-body section contains the lower transition area, main mid-body area and that part of the upper transition area in way and the stern section contains the stern area and that part of the upper transition area in way. These divisions are shown in Fig. 9.8.1 and further defined in 8.3.6 and 8.3.21.

8.3.6 The bow section is that region between the forward boundary of the mid-body section and the stem, *see also* 8.3.9.

8.3.7 The mid-body section has its aft boundary a distance *S* forward of the A.P. and its forward boundary, except as provided by 8.3.9, a distance *F* aft of the F.P. The distances *F* and *S* are given in Fig. 9.8.1.

8.3.8 The stern section is that region between the stern and the aft boundary of the mid-body section.



	H cm	*AW* cm	*BW* cm	*UT* cm	*LT* cm	*C* cm	*E* %L	*F* %L	*S* %L
Ice Class AC1	200	180	250	50	70	180	2,5	30	20
Ice Class AC1,5	300	240	375	75	110	240	2,5	30	20
Ice Class AC2	400	300	500	100	150	300	2,5	30	20
Ice Class AC3	600	515	850	170	260	515	2,5	30	25

Fig. 9.8.1 Regions and zones (multi-year ice conditions)

8.3.9 Where the shoulder of the ship consists of a pronounced hard chine, this may be taken as the basis of the boundary between the bow and mid-body sections of the hull. This chine may be in the form of a reamer or of a knuckle line. In the latter case, an overlap of the bow section beyond this line by the lesser of 0,04*L* or 5 m may be necessary.

8.3.10 The main bow area is part of the bow section and extends vertically above the keel to a line a distance, *H*, above the Ice Load Waterline or Deepest Ice Operating Waterline, if applicable, at the F.P., and a distance *AW* above these waterlines at the main mid-body area, but need not include the area defined as lower bow area.

8.3.11 The main mid-body area is part of the mid-body section and extends vertically from a line a distance *BW* below the Ice Light Waterline to a line a distance *AW* above the Ice Load Waterline or Deepest Ice Operating Waterline, if applicable. The distances *BW* and *AW* are given in Fig. 9.8.1.

8.3.12 The stern area is part of the stern section. It has its upper edge a distance *AW* above the Ice Load Waterline or Deepest Ice Operating Waterline at its fore end and a distance *C* above these waterlines at the A.P. The lower edge of the stern region is a distance (*BW* + *LT*), below the Ice Light Waterline. The distances *AW*, *C* and *LT* are given in Fig. 9.8.1.

8.3.13 The main ice belt zone comprises the main bow area, main mid-body area and stern area.

8.3.14 The upper transition area extends a distance, *UT*, above the main ice belt zone.

8.3.15 The lower transition area is part of the mid-body section. Aft of amidships, it extends below the main mid-body area by a distance *LT*. Forward of amidships, its lower edge is a line drawn from a point a distance *LT* below the main mid-body area at amidships to the junction of the bilge boundary line with the aft end of the main bow area.

8.3.16 The lower bow area is that part of the bow section below the main bow area. Its upper edge is a line drawn from a point at the aft end of the bow section set a distance *BW* below the Ice Light Waterline to a point on the keel line set a distance *E* aft of the bow line's departure from the level keel line.

8.3.17 The lower transition area need not extend below the bilge boundary line by more than the value of *LT* (*see* Fig. 9.8.1) measured around the circumference of the bilge.

8.3.18 The Ice Belt comprises the main Ice Belt Zone together with the lower bow area and the upper and lower transition areas.

8.3.19 Displacement, Δ, is the displacement in tonnes at the Ice Load Waterline, or Deepest Ice Operating Waterline, if applicable, when floating in water having a relative density of 1,0.

8.3.20 Shaft power, P_0 (H_0) is the maximum propulsion shaft power in kW (horsepower) for which the machinery is classed, *see* Pt 5, Ch 1,3 and Pt 5, Ch 9,1.3.

8.3.21 Bilge boundary line is that line which in elevation is parallel to the keel and at amidships is coincident with the upper turn of bilge.

8.4 Arrangement

8.4.1 The ballast capacity of the ship should be sufficient to give adequate propeller immersion in all ice navigating conditions. It is anticipated that the propeller tips at their highest point will not be closer to the Ice Light Waterline than the distance given in Table 9.8.1.

Table 9.8.1 Propeller tip minimum distance

Class	Ice Light Waterline Propeller tip minimum distance, in metres
Ice Class AC1	3,0
Ice Class AC1,5	3,75
Ice Class AC2	4,5
Ice Class AC3	6,0

8.4.2 It is recommended that the minimum draught at the fore-end should be not less than:

$$T_f = \left(1,5 + 0,1\sqrt[3]{\Delta}\right) h \quad \text{m}$$

where

h = the nominal ice thickness, in metres, associated with the desired Ice Class notation, *see* 8.1.

Δ = displacement as defined in 8.3.

8.4.3 All wing ballast tanks adjacent to the shell are to be supplied with heating pipes. All deck machinery such as mooring winches, windlass and essential parts of ice management systems, etc., should be equipped with an efficient de-icing system.

8.4.4 The bow should be such as to break ice effectively. The rake of stem should, in general, be less than 30° relative to the horizontal for Ice Classes AC1,5, AC2 and AC3. Apart from spoon shaped bow forms, the entry angle of the portion of the fore-body below the deepest ice waterline should not exceed 30°. Bulbous bows are not to be fitted to ships having Ice Class AC notations.

8.4.5 Where flare of the side shell amidships is proposed, it is recommended the slope of the side should be at least 8°.

8.4.6 For ships provided with a heel inducing system, it is recommended that the depth of the ship is such that immersion of the deck edge does not occur when the ship, whilst floating at the Ice Load Waterline or Deepest Ice Operating Waterline as applicable, is heeled to an angle of 5° greater than the nominal capacity of the system or 15° whichever is the greater.

8.4.7 It is recommended that the upper deck bulwark is sloped inboard and efficiently supported by transverse stays spaced at no more than 1,5 m, *see also* Ch 8,5.

8.4.8 The aft body of icebreaking ships should have a form such that broken ice is effectively displaced.

8.4.9 Where it is desired to make provision for close tow-push operations, the bow area should be suitably reinforced. Similarly, it is recommended that suitable reinforcements are arranged in way of the stern fork.

8.5 Longitudinal strength

8.5.1 The section modulus at deck and keel of vessels having Ice Class AC notations is to be increased above that required in Pt 3, Ch 4,5 to take account of beaching and dynamic impact loads during ice-breaking operations. Relevant calculations are to be submitted. For initial structural design guidance, the minimum required section modulus of ice-breaking ships would normally be expected to be greater than:

$$Z_{act} = K Z_{min}$$

where K is a modulus amplification factor depending on L as follows:

L (m)	K
50	1,80
75	1,58
100	1,45
150	1,30
200 and over	1,20

The midship scantlings of the main longitudinal members are to be maintained between 0,2L aft of amidships and 0,3L forward of amidships. However, these scantlings are to extend to at least B/3 forward of the position of the maximum bending moment obtained from the simulated beaching calculations carried out in the structural design of these ships. The position of this maximum bending moment is to be indicated on the submitted plan. The corrosion-abrasion increment required for the shell plating given in Table 9.8.5 is not to be included in the calculation of the actual modulus.

8.5.2 The maximum permissible still water bending moment $|\overline{M}_s|$ which can be assigned to ships having Ice Class AC notations is as follows:

(a) Non-Ice-transiting voyages:
$|\overline{M}_s|$ is to be calculated from Ch 4,5.4.

(b) Ice-transiting or partially Ice-transiting voyages:
$|\overline{M}_s|$ is to be taken as 95 per cent of the value calculated from Ch 4,5.4, taking F_B = 1,0 and F_D as calculated from Ch 4,5.6.

8.6 Bulkheads

8.6.1 Bulkheads are to be arranged in accordance with the requirements given in Table 9.8.2, *see also* Ch 3,4.

8.6.2 It is recommended that vertically stiffened transverse bulkheads are fitted with additional horizontal stiffening to resist buckling.

Table 9.8.2 Bulkhead arrangements

Class	Longitudinal bulkheads minimum requirements	Transverse bulkheads(1) (2) maximum spacing
Ice Class AC1	1 – fwd. 0,4L(1) (4)	Lesser of 0,14L or 40 m
Ice Class AC1,5	Double skin for full length of ship(3)	
Ice Class AC2	Double skin for full length of ship(3) plus 1 – fwd. 0,4L(1)	
Ice Class AC3	Double skin for full length of ship(3) plus 3 – fwd. 0,4L(1) 1 – aft 0,6L(1)	

NOTES
1. May be watertight or non-watertight.
2. In the case of ships intended to navigate in Canadian Arctic waters attention is drawn to the requirements of the Arctic Shipping Pollution Prevention Regulation C353 in respect to subdivision standards.
3. The minimum width of the side tanks formed by the double skin should not be less than 1,2 m and the vertical extent of these tanks should be at least up to the bulkhead deck.
4. It is recommended that double skin is also adopted for this Class.

8.7 Bottom structure

8.7.1 The maximum spacing of floors should not exceed 2(550 + 1,667L) or 1700 mm whichever is the lesser. The maximum spacing of side girders in the double bottom should not exceed 1,6 m. Special consideration will be given to ships having deep draughts.

8.7.2 Ships designed to operate in ice conditions at shallow draught, i.e. at a draught less than indicated by 8.4.2, will require additional strengthening of bottom shell structure forward. Spacing of floors forward for such ships should not exceed 1,0 m. Bottom shell and bottom shell longitudinals will be specially considered. The spacing of side girders forward should not exceed 1,4 m.

8.8 Powering of ships intended to operate in multi-year ice conditions

8.8.1 The total shaft power installed in icebreaking ships intended to operate in Canadian Arctic regions should be not less than that required by the Canadian Arctic Shipping Pollution Prevention Regulations. For other regions, the minimum power is to be not less than that obtained by 8.8.3 taking the ship's speed as 1 knot.

8.8.2 Ships intended to operate in multi-year ice conditions should, in general, be able to develop sufficient thrust to permit continuous mode ice-breaking at a speed of five knots assuming the ice thickness related to the required Ice Class AC notation as given in 8.1. Snow cover should be assumed to be at least 0,3 m.

8.8.3 The requirements of 8.8 to 8.18 are formulated on the basis that the power necessary to provide the independent icebreaking capability described in 8.7.2 can be determined by the equation:

$$P_1\,(H_1) = C_0\,C_1\,C_2\,C_3\left(240B\,h\,(1 + h + 0{,}035v^2) + 70S_c\sqrt{L}\right)\ \text{kW (shp)}$$

where

h = ice thickness for desired Ice Class AC notation, *see* 8.1
v = ship speed (knots) when breaking ice of thickness h
C_0 = 0,736 (1,0)
$C_1 = \dfrac{1{,}2B}{\sqrt[3]{\Delta}}$
but to be taken as not less than 1,0
C_2 = 0,9 if ship fitted with controllable pitch propeller, otherwise 1,0
C_3 = 0,9 if the rake of stem is 45° or less, otherwise 1,0. The product $C_2\,C_3$ is not to be taken as less than 0,85
S_c = depth of snow cover, in metres
Δ = displacement as defined in 8.3.19.

8.8.4 The ice strengthening requirements set out in 8.9 to 8.15 include a power-displacement correction factor which is to be determined as follows:
(a) Bow section
$\gamma = (0{,}88 + 0{,}0103f - 2{,}232f^2 \times 10^{-4})\,(1 + A\,(F - 1))$
(b) Stern and mid-body sections
$\gamma = 0{,}7 + 0{,}00924f - 2{,}134f^2 \times 10^{-4}$

where

$f = \sqrt{P_0\,\Delta} \times 10^{-3}\ \left(= 0{,}858\sqrt{H_0\,\Delta} \times 10^{-3}\right)$
but is not to be taken greater than 22
A = 0,1 for shell plating
= 0 for frames, stringers and web-frames
F = ratio of installed power P_0 (H_0) to the power $P_1(H_1)$ calculated in accordance with 8.8.2 and 8.8.3 but is not to be taken as less than 1,0

and P_0, H_0, Δ are defined in 8.3.19 and 8.3.20.

8.9 Shell plating

8.9.1 In way of the Ice Belt, the thickness of the shell plating is not to be less than:

$$t = 0{,}5s\,\alpha_p\,\beta\,\gamma\sqrt{\frac{p}{\sigma_o}} + c\ \ \text{mm}$$

in association with transverse or longitudinal framing,
where

c = corrosion-abrasion increment as given in Table 9.8.5
p = design ice pressure for each Ice Class as given in Table 9.8.4
s = frame spacing between adjacent frames, in mm
α_p = longitudinal distribution factor dependent upon Ice Class AC notation and longitudinal position as given in Table 9.8.3
β = vertical distribution factor dependent on vertical position as given in Table 9.8.6
γ = power-displacement factor as defined in 8.8.4
σ_o = specified minimum yield stress of steel in N/mm^2 (kgf/mm^2). For mild steel, the value of 235 N/mm^2 (24 kgf/mm^2) is to be used.

~~**Table 9.8.3 Longitudinal distribution factor α_p**~~

Class	α_p		
	Bow	Mid-body	Stern
Ice Class AC1	1,0	0,8	0,9
Ice Class AC1,5	1,31	1,05	1,16
Ice Class AC2	1,6	1,28	1,45
Ice Class AC3	2,1	1,7	1,9

Table 9.8.4 Design ice pressure *p*

Class	Design ice pressure, p N/mm^2 (kgf/mm^2)
Ice Class AC1	5,89 (0,60)
Ice Class AC1,5	5,40 (0,55)
Ice Class AC2	4,91 (0,50)
Ice Class AC3	3,92 (0,40)

Table 9.8.5 Corrosion-abrasion increment *c*

Class	Corrosion-abrasion increment, c (mm)
Ice Class AC1	5
Ice Class AC1,5	6
Ice Class AC2	7
Ice Class AC3	9

Table 9.8.6 Vertical distribution factor β

Vertical position	β
Main ice belt zone	1,0
Upper transition area:	
Above main bow area	0,8
Above main mid-body area	0,5
Above main stern area	0,5
Lower transition area	0,5
Lower bow area	0,5

8.10 Transverse framing

8.10.1 The section modulus of main and intermediate transverse frames in way of the ice belt (including a width of attached plating equal to s) is to be not less than that determined in accordance with the following:

$$Z = 40\,\alpha_t\,\beta\,\gamma\,\frac{p\,s\,h_o}{l\,\sigma_o}\left(3l^2 - h_o^2\right)\ \text{cm}^3$$

where

h = as defined in 8.7.3

h_o = ice bearing height, dependent upon the span l, as given in Table 9.8.7 but is to be taken as not greater than the design ice thickness h or the span ~~l, whichever is the least~~

~~l = span, in metres, measured along a chord at the~~ side between the span points. For definition of span points, *see* Ch 3,3.3. Where adjacent main and intermediate frames have different end connections, resulting in different spans, a mean value is to be used

p = the ice pressure dependent upon ice bearing height, h_o, as given in Table 9.8.10

s, σ_o = as defined in 8.9.1

α_t = longitudinal distribution factor dependent on ice bearing height, h_o, and longitudinal position as given in Table 9.8.8

β = vertical distribution factor on vertical position and given in Table 9.8.9

γ = as defined in 8.8.4.

Table 9.8.7 Ice bearing height h_o

Span l m	Ice bearing height, h_o m
Less than 1,5	1,0
$1,5 \leq l < 2,2$	1,5
$2,2 \leq l < 4$	2
4 or greater	3

NOTE
h_o is not to be taken greater than the value of ice thickness, h, implied by the Ice Class AC notation.

Table 9.8.8 Longitudinal distribution factor α_t

Ice bearing height, h_o m	α_t		
	Bow	Mid-body	Stern
1 or less	1,0	0,8	0,9
1,5	0,95	0,76	0,86
2	0,91	0,73	0,82
3 or greater	0,86	0,69	0,78

Table 9.8.9 Vertical distribution factor β

Vertical position	β
Main ice belt zone	1,0
Upper transition area	0,5
Lower transition area	0,7
Lower bow area	0,5

Table 9.8.10 Ice bearing height h_o

Ice bearing height, h_o m	p N/mm^2 (kgf/mm^2)
1,0 or less	5,89 (0,6)
1,5	5,40 (0,55)
2,0	4,91 (0,50)
3 or greater	3,92 (0,40)

8.10.2 The cross-sectional shear area of transverse main and intermediate frames is to be not less than determined in accordance with the following formula:

$$A = 13\alpha_t \, \beta \, \gamma \, h_o \, \frac{ps}{\sigma_o} \quad \text{cm}^2$$

where

h_o = ice bearing height to be taken as equal to the span, l, but is not to be taken as greater than the design ice thickness for the desired Ice Class as given in 8.1

p = design ice pressure dependent upon ice bearing height, h_o, as given in Table 9.8.10. Linear interpolation is to be used for intermediate values of h_o

α_t = longitudinal distribution factor dependent on ice bearing height, h_o, and longitudinal position as given in Table 9.8.8. Linear interpolation is to be used for intermediate values of h_o

l, β as defined in 8.10.1

s, σ_o as defined in 8.9.1

γ as defined in 8.8.4.

8.10.3 The main and intermediate frames of the main ice belt zone, having scantlings as required by 8.10.1 and 8.10.2, should be extended to the first primary longitudinal member above or below this zone. The end connections of these frames to the primary longitudinal members are to be bracketed. Where the side frames are flat bar sections, they may be extended through the primary longitudinal member, suitably tapered and butt welded to the flat bar side frames required for the upper and lower transition areas.

8.10.4 The main and intermediate frames of the upper transition and lower transition areas, having scantlings as required by 8.10.1 and 8.10.2, should be extended, in the case of the upper transition area, to the first primary member above this area and for the lower transition area continued to the double bottom and/or margin plate as applicable. These frames should be effectively bracketed to the primary longitudinal member.

8.10.5 In the context of 8.10.3 and 8.10.4, a primary longitudinal member is defined as either a deck, deep tank top, or ice stringer complying with 8.13.

8.10.6 The intermediate frames need not extend beyond the limits defined in 8.10.4 provided that, in the case where the primary longitudinal member is an ice stringer, a suitable extension bracket is fitted.

8.11 Longitudinal framing

8.11.1 The section modulus of longitudinal frames (including a width of attached plating s) is to be not less than that determined in accordance with the following:

$$Z = 56\alpha_l \, \beta \, \gamma \, s \, l^2 \, \frac{p}{\sigma_o} \quad \text{cm}^3$$

l = span of longitudinal, in metres, determined in accordance with Ch 3,3.3

p = 5,89 (0,60)

s = longitudinal frame spacing, in mm

α_l = longitudinal distribution factor as given in Table 9.8.11

Table 9.8.11 Longitudinal distribution factor α_l

Class	α_l		
	Bow	Mid-body	Stern
All ice classes	1,0	0,8	0,9

Table 9.8.12 Vertical distribution factor β

Vertical position	β
Main ice belt zone	1,0
Upper transition area:	
Above main bow area	1,0
Above main mid-body area	0,7
Above main stern area	1,0
Lower transition area	0,7
Lower bow area	0,8

β = vertical distribution factor as given in Table 9.8.12

γ, σ_o = is as defined in 8.8.4 and 8.9.1.

8.11.2 The cross-section shear resisting area of longitudinal frames is to be not less than that determined in accordance with the following:

$$A = 13\alpha_l \, \beta \, \gamma \, s \, l \, \frac{p}{\sigma_o} \quad \text{cm}^2$$

where

α_l, β, l, p, s are defined in 8.11.1

σ_o is defined in 8.9.1

γ is defined in 8.8.4.

8.12 Framing – General requirements

8.12.1 In general, the web thickness of frames within the ice belt is to be not less than half that of the attached shell plating and the depth to thickness ratio for flat bar frames and longitudinals not greater than 15.

8.12.2 Where a frame intersects a boundary between two hull sections, the scantling requirements applicable will be those for the bow section, if the boundary between the bow and mid-body sections is intersected, or those for the stern section, if the boundary between the stern and mid-body sections is intersected.

8.12.3 Main and intermediate frames within the ice belt are to be efficiently supported to prevent tripping as shown in Fig. 9.7.6. The distance between anti-tripping supports is not to exceed 1,0 m.

8.12.4 Frames within the ice belt are to be attached to the shell plating by double continuous welding and are not to be scalloped except in way of shell butts.

8.12.5 The effective weld area attaching frames to primary members is to be not less than the shear area for the frames as required by 8.10.2 or 8.11.2 as appropriate.

8.12.6 For bulkheads or decks within the ice belt, the thickness of the plating adjacent to the shell is to be not less than that of the web of the adjacent frame. This increased thickness should extend for a width sufficient to give an area equal to that required for such frames.

8.13 Primary longitudinal members supporting transverse ice framing

8.13.1 The section modulus of ice stringers or of decks adjacent to hatchways, including a width of attached plating determined in accordance with Ch 3,3.2, and taken about an axis perpendicular to the web, is to be not less than that given by:

$$Z = 16\,700\, \alpha_o\, \beta\, \gamma^2\, S\, l^2\, \frac{p}{\sigma_o} \quad \text{cm}^3$$

where

l = span of member, in metres, measured between span points but is to be taken as not less than 1,6 m

p = design ice pressure for desired Ice class as given in Table 9.8.4

S = spacing of primary longitudinal members, in metres, but need not be taken as greater than h, the nominal ice thickness for desired Ice Class as given in 8.1

α_o = longitudinal distribution factor as given in Table 9.8.13

β = vertical distribution factor as given in Table 9.8.14.

and γ, σ_o as given in 8.8.4 and 8.9.1.

Table 9.8.13 Longitudinal distribution factor α_o

Class	α_o		
	Bow	Mid-body	Stern
Ice Class AC1	1	0,9	0,95
Ice Class AC1,5	1,13	1,02	1,07
Ice Class AC2	1,8	1,6	1,7
Ice Class AC3	2,5	2,25	2,4

Table 9.8.14 Vertical distribution factor β

Vertical position	β
Main ice belt zone	1,0
Upper transition area:	
In way of bow section	0,9
In way of mid-body section	0,7
In way of stern section	0,8
Lower transition area	0,7
Lower bow area	0,9

8.13.2 The cross-sectional shear resisting area of ice stringers or of decks adjacent to hatchways is to be not less than that determined in accordance with the following:

$$A = 3000\, \alpha_o\, \beta\, \gamma^2\, S\, l^2\, \frac{p}{\sigma_o} \quad \text{cm}^3$$

where

α_o, β, l, p and S are defined in 8.13.1

γ, σ_o are defined in 8.8.4 and 8.9.1.

8.13.3 Primary longitudinal members supporting tranverse frames should normally be arranged so that the maximum deviation of their webs from the perpendicular to the shell plating does not exceed ±20 degrees. Arrangements based on horizontal side stringers will be acceptable only if the section modulus is related to the axis parallel to the shell plating and brackets extending the full depth of the web are arranged at every transverse frame.

8.13.4 In all cases, the transverse frames are to be attached to the ice stringers by flat bars extending the full depth of the web of the primary longitudinal member. These flat bars should be fitted to both sides of the primary longitudinal member in vessels having designations Ice Class AC2 and AC3.

8.13.5 The minimum thickness of the web plating of longitudinal primary members is to comply with the requirements of Ch 10,4.

8.14 Web frames

8.14.1 The section modulus of web frames supporting ice stringers or longitudinal ice frames, including a width of attached plating determined in accordance with Ch 3,3.2 and taken about an axis perpendicular to the web, is to be not less than that given by:

$$Z = 8300\, \alpha_o\, \beta\, \gamma^2\, \frac{Sp}{l\, \sigma_o}\, h_o \left(3l^2 - h_o^2\right) \quad \text{cm}^3$$

where

h = nominal ice thickness for desired Ice Class as given in 8.1

h_o = ice bearing height, in metres, to be taken as equal to the ice thickness h but is not to exceed the span l

l = web frame span, in metres, measured along a chord at side between span points but is to be taken as not less than 2 m. For definition of span points, *see* Ch 3,3.3

p = design ice pressure as given in Table 9.8.10

S = web frame spacing, in metres

α_o = longitudinal distribution factor as given by Table 9.8.13

β = vertical distribution factor as given by Table 9.8.14

γ, σ_o are defined in 8.8.4 and 8.9.1.

8.14.2 The cross-sectional shear resisting area of web frames supporting ice stringers or longitudinal ice frames is to be not less than that determined in accordance with the following:

$$A = 3000\, \alpha_o\, \beta\, \gamma^2\, S\, h_o\, \frac{p}{\sigma_o} \quad \text{cm}^2$$

where

α_o, β, *S, p* and h_o are defined in 8.14.1
γ, σ_o are defined in 8.8.4 and 8.9.1.

8.14.3 The thickness of the web plating of web frames below the upper deck level is to be not less than one per cent of the web depth or the thickness given in Table 9.8.15 whichever is the greater, *see also* 8.14.6.

Table 9.8.15 Web frame thickness

Class	Minimum web thickness of web frames mm
Ice Class AC1	12
Ice Class AC1,5	15
Ice Class AC2	18
Ice Class AC3	20

8.14.4 The minimum thickness of the face flat attached to the web frame is to be not less than 10 mm greater than the minimum web thickness as given by 8.14.3 and the minimum width of the face plate should be not less than 15 per cent of the web depth.

8.14.5 The spacing of tripping brackets supporting web frames should not exceed 2 m in the main ice-belt zone and 2,5 m elsewhere.

8.14.6 Where longitudinal frames pass through web frames, watertight or non-watertight bulkheads, the thickness of these members, adjacent to the shell plating, is to be not less than 60 per cent of the thickness of the longitudinals.

8.14.7 The longitudinal frames should be connected to the web frames by a flat bar extending the full depth of the web frame. In the case of Ice Class AC1,5, Ice Class AC2 and Ice Class AC3, this connection should be effected by double brackets.

8.15 Stem

8.15.1 The stem is to be made from rolled, cast or forged steel or of shaped steel plates.

8.15.2 The plate thickness of a plate stem is to be not less than:

$$t = 0{,}5s\, \alpha_p\, \beta\, \gamma\, \frac{p}{\sigma_o} + c \quad \text{mm}$$

where

α_p, β, γ, σ_o, *p, c* are defined in 8.9.1

and

s = distance, in mm, between horizontal webs and diaphragm plates having a thickness of at least 0,5*t*.

8.15.3 The thickness of the stem plate is to be not less than 1,1 times the thickness of the adjacent plating in the bow section as determined by 8.9.1.

8.15.4 Where a forged or cast steel stem profile is incorporated, the extent of the ice reinforced profile is to extend to at least the upper edge of the upper transition zone. The connection of the shell plating to the stem is to be flush. Similar requirements apply to welded stem constructions.

8.15.5 The stem should extend to the forefoot ice arrester structure. Ice arresters are recommended for all ships having Arctic Ice Class AC notations to prevent riding up of the bow and submergence of the aftermost deck edge.

8.16 Stern

8.16.1 Where the screwshaft diameter exceeds the Rule diameter, the propeller post is to be correspondingly strengthened, *see* Ch 6,7.

8.16.2 A transom stern should not normally extend below the Ice Load Waterline. Where this cannot be avoided, the transom should be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the stern section.

8.16.3 Where special provision is made in the stern area of the vessel for close tow-push operations, the fork structure should be of sufficient strength to transmit the applied forces.

8.17 Bossings and shaft struts

8.17.1 Shaftings and sterntubes of ships with two or more propellers are to be enclosed within plated bossings.

8.18 Rudder, steering arrangements and nozzles

8.18.1 In general, spade rudders are not to be fitted on ships employed in Arctic or Antarctic operations.

8.18.2 Rudder posts, rudder horns, solepieces, rudder stocks and pintles are to be dimensioned in accordance with Chapter 6 or Chapter 13 as appropriate. The speed used in the calculations is to be the maximum service speed or that given in Table 9.8.16, whichever is the greater. However, the section modulus of the solepiece calculated in accordance with the above need not be greater than three times the section modulus of solepiece calculated in accordance with Ch 6,7 using the maximum service speed.

8.18.3 For double plate rudders, the minimum thickness of plates and horizontal and vertical webs in the main ice-belt zones is to be determined as for the shell plating in the stern area, as required by 8.9.1. Horizontal and vertical webs, however, need not include the corrosion abrasion increment of Table 9.8.5.

Table 9.8.16 Minimum speed

Class	Minimum speed knots
Ice Class AC1	22
Ice Class AC1,5	23
Ice Class AC2	24
Ice Class AC3	26

8.18.4 The rudder head and upper edge of the rudder are to be efficiently protected against ice impact, when the ship is backing into ice, by a robust ice knife. The thickness of the boundaries of this ice knife structure is to be not less than that of the rudder side plating. The width of the ice knife should exceed the maximum width of the rudder by five per cent.

8.18.5 Fixed nozzles are to be effectively integrated into the aft end structure. Where a twin screw nozzle arrangement is fitted, a heavy skeg is to be arranged in front of each nozzle. For such an arrangement it is considered advisable to keep the distance between the nozzles to a minimum in order to restrict ice flow between the nozzles. The head box structure should contain a dense grillage of longitudinal and transverse plate girders. Particular attention is to be paid to all structural details and especially the connections between the nozzle and the solepiece. Freely suspended nozzles are not considered suitable for icebreaking duties.

8.18.6 The nozzle construction requirements of Table 13.3.1 in Ch 13,3 should be upgraded for ships having Ice Class AC notations to include the abrasion allowance given in Table 9.8.17. However, the thickness of the shroud plating is to be not less than the shell plating in the stern area as determined by 8.9.1 taking the frame spacing, *s*, as 350 mm, but need not exceed 45 mm.

Table 9.8.17 Abrasion allowance

Class	Abrasion increment
Ice Class AC1	8
Ice Class AC1,5	10
Ice Class AC2	12
Ice Class AC3	15

8.18.7 The scantlings of nozzle stock, gudgeon, pintles, solepiece, etc., determined in accordance with Ch 13,3, should be increased on the basis of 8.17.2. However the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as half the speed given in Table 9.8.16 or the actual stern speed, whichever is the greater. The allowable stresses to be used in the calculation of nozzle stock diameter are to be taken as:

combined stress at lower bearings ≤ 85 N/mm^2 (8,7 kgf/mm^2)

torsional stress in upper stock ≤ 55 N/mm^2 (5,6 kgf/mm^2)

8.18.8 The section modulus of the solepiece obtained from 8.18.7 is to be not less than that determined in accordance with the following:

$$Z = C Z_s \text{ cm}^3$$

where

Z_s = modulus of the solepiece calculated using the Rule stress given in Ch 13,3

C = *see* Table 9.8.18

For the ahead condition, the maximum service speed is to be used and for the astern condition, the greater of half the maximum service speed or the astern speed.

Table 9.8.18 Values of *C*

Class	*C*
Ice Class AC1	1,5
Ice Class AC1,5	2
Ice Class AC2	2,5
Ice Class AC3	3,0

8.18.9 Nozzles with articulated flaps will be subject to special consideration.

8.18.10 Where the nozzle numeral as per Table 13.3.1, in Chapter 13, exceeds 400 an analysis of the nozzle structure should be carried out including appropriate simulation of ice impact loading.

8.18.11 It is advisable to verify that the natural frequency of the nozzle arrangement immersed in water is well removed from the excitation frequencies.

8.18.12 Due regard is to be paid to the method of securing the rudder in the centreline position when backing into ice. Where possible, rudder stoppers working on the blade or rudder head should be fitted.

8.18.13 Ships having Ice Class AC notations are, in addition to the main steering gear, to be fitted with auxiliary steering gear capable of being readily connected to the tiller, *see also* Pt 5, Ch 19. In the case of twin rudders operated by a single steering gear, there is to be provision for each rudder to be readily disconnected and secured.

8.18.14 The main steering gear of ships having Ice Class AC notations shall be fitted with a shock absorbing device and be capable of moving the rudder from 35° on one side to 30° on the other side in 6,56*L* seconds or 28 seconds, whichever, is the lesser when the ship is fully loaded and travelling at her maximum service speed.

8.19 Direct calculations

8.19.1 If, as an alternative to the requirements of 8.12 and 8.13, the scantlings of primary longitudinal members and web frames are determined by direct calculation as permitted by Ch 1,2.1, the following procedure is to be adopted:

(a) The extent of the structural model should be at least equal to the largest cargo hold length between two transverse bulkheads. The upper boundary should be the upper deck and the lower boundary the inner bottom.

(b) The structural members represented should include stringers, web frames, side frames and all relevant decks.

(c) The rate of applied ice loading q, for the mid-body section, should be taken as:
$q = p\,h\,10^3$ kN/m (tonne-f/m)
where p is given in Table 9.8.4
h is defined in 8.4

(d) The scantlings should be suitable for the centre of load depth to be located at any height between the Ice Load Waterline and Ice Light Waterline.

(e) The maximum von Mises-Hencky combined stress is not to exceed 80 per cent of the yield stress of the steel.

CORRIGENDA

■ *Section 9*
Strengthening requirements for navigation in very light first-year ice conditions

9.1 General

9.1.1 These requirements apply to offshore supply ships, as defined in Pt 4, Ch 4, and which are intended to operate in very light first-year ice conditions. Where additional strengthening is fitted in accordance with the requirements of this sub-Section, the notation Ice Class **1E** will be assigned.

9.1.2 For longitudinally framed ships, the scantlings of shell plating and framing are to comply with the requirements of Ice Class **1C FS** using 0,9 times the ice pressure. The requirements for shell plating need only be applied in the region shown in Fig. 9.1.1. The requirements for framing need only be applied forward of the flat of side.

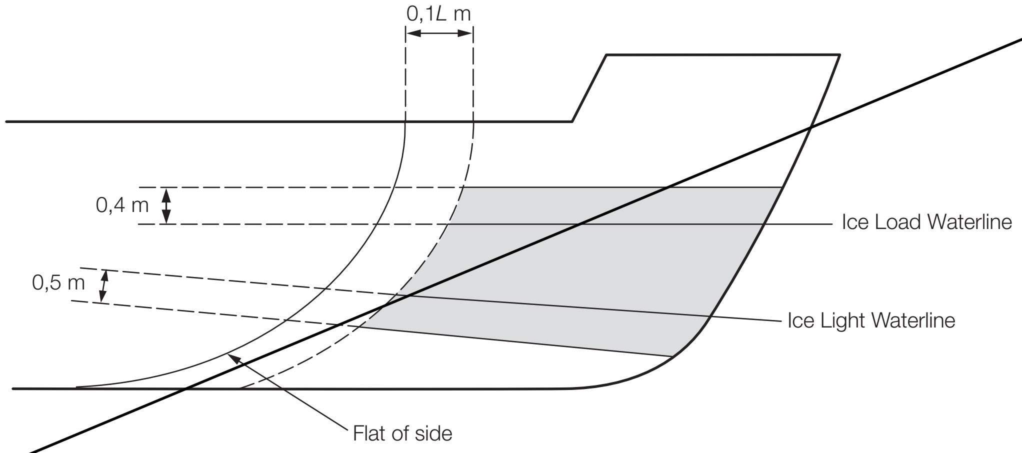
9.1.3 For transversely framed ships, the requirements of 9.3 to 9.8 are to be applied.

9.1.4 Where the structural requirements of Ice Class **1C FS** give lesser scantlings than the requirements of this sub-Section, the lesser scantlings may be applied.

9.2 Shell plating

9.2.1 The shell plating thickness within the region shown in Fig. 9.1.1 is not to be less than:

$$t = 21{,}75s \quad k\left(\frac{BL^2}{110000} + 1\right)\left(1{,}3 - \frac{4{,}2}{(0{,}26/s + 1{,}8)^2}\right) + 2\ \text{mm}$$



Ice Load Waterline and Ice Light Waterline are defined in 7.2
L, as defined in Ch 1,6.1

Fig. 9.1.1 Extent of application of plating requirements

where

s = spacing of main frames, in metres

L and B are defined in Ch 1,6.1

k is defined in Ch 2,1.2.

9.3 Transverse framing

9.3.1 The section modulus of main frames forward of the flat of side is not to be less than:

$$z = 6{,}08 s\, l\, k \left(\frac{BL^2}{140000} + 1{,}23 \right) \left(7 - \frac{1}{21} \right) \text{ cm}^3$$

but need not be taken as greater than:

$$z = sLT$$

where

s = spacing of main frames, in metres

l = span, in metres

L and B are defined in Ch 1,6.1

k is defined in Ch 2,1.2.

9.3.2 Intermediate ice frames are to be fitted in the region forward of the flat of side and are to extend from 0,62 m above the Ice Load Waterline to 1 m below the Ice Light Waterline.

9.3.3 Intermediate ice frames aft of the collision bulkhead are to have a section modulus not less than 65 per cent of that given in 9.3.1.

9.3.4 Intermediate ice frames forward of the collision bulkhead are to have a section modulus not less than 40 per cent of that given in 9.3.1.

9.4 Primary longitudinal members supporting ice frames

9.4.1 Forward of the collision bulkhead, in single deck ships, an ice stringer is to be fitted approximately 0,25 m below the Ice Load Waterline and is to have scantlings in accordance with Table 5.4.4 in Chapter 5.

9.4.2 Aft of the collision bulkhead a series of tripping brackets are to be fitted at each main and intermediate frame at the same level as the ice stringer to a distance 0,1L aft of the flat of side.

9.5 Sternframe and rudder

9.6.1 The rudder and sternframe scantlings are to be in accordance with 7.7. However, the ship's speed need not be taken as greater than 14 knots. The hull form factor and the rudder profile coefficients are to be taken as 1,0.

9.6 Weld connections

9.6.1 Weld connections to the shell plating forward of the collision bulkhead are to be double continuous.

Effective date 1 March 2008

Existing Sections 10 to 13 are to be renumbered 6 to 9.

Part 5, Chapter 9
Strengthening for Navigation in Ice

Effective date 1 March 2008

■ ~~*Section 1*~~
General

1.1 Class notations

1.1.1 For ships where ice class notation **Ice Class 1AS FS, Ice Class 1A FS, Ice Class 1B FS** or **Ice Class 1C FS** is requested, the requirements of this Chapter, as applicable, in addition to the Finnish Swedish Ice Class Rules in force at the time of contract, are to be complied with. Section 2 of this Chapter replaces Section 6 of the Finnish Swedish Ice Class Rules.

1.1.2 Ships strengthened in accordance with the requirements of **Ice Class 1D** are not intended for operation in the northern part of the Baltic in the winter season. For ships where **Ice Class 1D** is requested, the requirements of Section 3 are to be complied with.

1.1.3 Offshore supply ships strengthened in accordance with the requirements of Ice Class **1E** are only intended for navigation in very light first-year ice conditions. The requirements of Section 3 are to be complied with.

1.1.4 For ships where the ice class notation **Ice Class 1AS FS(+), Ice Class 1A FS(+), Ice Class 1B FS(+)** or **Ice Class 1C FS(+)** is requested, the requirements of Sections 2 and 4 of this Chapter, in addition to the Finnish Swedish Ice Class Rules, in force at the time of contract, are to be complied with. The Finnish Swedish Ice Class Rules may be obtained from the following website:

www.fma.fi

1.2 Materials for shafting

1.2.1 All components of the main propulsion system are to be of steel or other approved ductile material.

1.2.2 For screwshafts in ships intended for the notation **Ice Class 1AS FS** or **Ice Class 1A FS** and where the connection between the propeller and the screwshaft is by means of a key, Charpy impact tests are to be made in accordance with the requirements of Ch 5,3.4.12 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.3 Materials for propellers

1.3.1 Propellers and propeller blades are to be of cast steel or copper alloys and are to be manufactured, tested and certified in accordance with Ch 4,1, Ch 4,5 and Ch 9,1 of the Rules for Materials respectively.

1.3.2 For steel propellers, the elongation of the material used is to be not less than 19 per cent for a test piece length ~~of 5*d*. Charpy impact tests are to be carried out in accordance with the requirements of the Rules for Materials.~~

1.3.3 Cast steel load transmitting components of controllable pitch mechanisms are to be manufactured, tested and certified in accordance with the requirements of Ch 4,5 of the Rules for Materials.

1.3.4 Forged steel load transmitting components of controllable pitch propellers are to be manufactured, tested, and certified in accordance with Ch 5,1 and Ch 5,2 of the Rules for Materials. Impact tests are to be carried out at minus 10°C and the average energy value is to be not less than 27J.

1.3.5 Spheroidal cast iron load transmitting-components of controllable-pitch mechanisms are to be manufactured, tested and certified in accordance with the requirements of Table 7.3.2 in Ch 7,3 of the Rules for Materials.

■ *Section 2*
Ice Classes 1AS FS, 1A FS, 1B FS and 1C FS

2.1 General

2.1.1 Where the notation **Ice Class 1AS FS**, **Ice Class 1A FS**, **Ice Class 1B FS** or **Ice Class 1C FS** is desired, the requirements of this Section, in addition to those for open water service, are to be complied with, so far as these are applicable.

2.2 Determination of ice torque

2.2.1 Dimensions of propellers, shafting and gearing are determined by formulae taking into account the impact when a propeller blade hits ice. The ensuing load is hereinafter defined by ice torque, *M*.

$M = m D^2$ kN m (tonne-f m)

where

m = 21,10 (2,15) for **Ice Class 1AS FS**
= 15,69 (1,60) for **Ice Class 1A FS**
= 13,04 (1,33) for **Ice Class 1B FS**
= 11,96 (1,22) for **Ice Class 1C FS**

D = diameter of propeller, in metres.

2.2.2 If the propeller is not fully submerged when the ship is in ballast condition, the ice torque for **Ice Class 1A FS** is ~~to be used for **Ice Class 1B FS** and **Ice Class 1C FS**.~~

2.3 Propeller blade sections

2.3.1 The width, L, and thickness, T, of propeller blade sections are to be determined so that:

(a) at the radius 0,25D/2, for solid propellers

$$LT^2 \geq \frac{26\,478\,000}{\sigma_u\,(0{,}65 + 0{,}7p_r/D)} \left(27{,}2\,\frac{P}{NR} + 2{,}24M\right)$$

$$\left(LT^2 \geq \frac{2\,700\,000}{\sigma_u\,(0{,}65 + 0{,}7p_r/D)} \left(20\,\frac{H}{NR} + 22M\right)\right)$$

(b) at radius 0,35D/2 for controllable pitch propellers

$$LT^2 \geq \frac{21\,084\,300}{\sigma_u\,(0{,}65 + 0{,}7p_r/D)} \left(27{,}2\,\frac{P}{NR} + 2{,}35M\right)$$

$$\left(LT^2 \geq \frac{2\,150\,000}{\sigma_u\,(0{,}65 + 0{,}7p_r/D)} \left(20\,\frac{H}{NR} + 23M\right)\right)$$

(c) at the radius 0,6D/2

$$LT^2 \geq \frac{9\,316\,320}{\sigma_u\,(0{,}65 + 0{,}7p_r/D)} \left(27{,}2\,\frac{P}{NR} + 2{,}86M\right)$$

$$\left(LT^2 \geq \frac{950\,000}{\sigma_u\,(0{,}65 + 0{,}7p_r/D)} \left(20\,\frac{H}{NR} + 28M\right)\right)$$

where

D = diameter of propeller, in metres
L = length of the expanded cylindrical section of the blade, at the radius in question, in mm
M = ice torque as defined in 2.2
N = number of blades
p_r = propeller pitch at the radius in question, for solid propellers, in metres
= 0,7 nominal pitch for controllable pitch propellers, in metres
$P(H)$ = shaft power as defined in Ch 1,3.3
R = propeller speed, in rev/min
T = the corresponding maximum blade thickness, in mm
σ_u = specified minimum tensile strength of the material, in N/mm^2 (kgf/mm^2).

2.3.2 Where the blade thickness derived from these formulae is less than the blade thickness derived by Ch 7,3.1 the latter is to apply.

2.4 Propeller blade minimum tip thickness

2.4.1 The blade tip thickness, t, at the radius D/2 is to be determined by the following formulae:

Ice Class 1AS FS

$$t = (20 + 2D)\sqrt{\frac{490}{\sigma_u}}\ \text{mm}$$

$$\left(t = (20 + 2D)\sqrt{\frac{50}{\sigma_u}}\ \text{mm}\right)$$

Ice Classes 1A FS, **1B FS** and **1C FS**

$$t = (15 + 2D)\sqrt{\frac{490}{\sigma_u}}\ \text{mm}$$

$$\left(t = (15 + 2D)\sqrt{\frac{50}{\sigma_u}}\ \text{mm}\right)$$

where D and σ_u are as defined in 2.3.

2.5 Intermediate blade sections

2.5.1 The thickness of other sections is to conform to a smooth curve connecting the section thicknesses as determined by 2.3 and 2.4.

2.6 Blade edge thickness

2.6.1 The thickness of blade edges is to be not less than 50 per cent of the derived tip thickness, t, measured at 1,25t from edge. For controllable pitch propellers this applies only to the leading edge.

2.7 Mechanisms for controllable pitch propellers

2.7.1 The strength of mechanisms in the boss of a controllable pitch propeller is to be 1,5 times that of the blade when a load is applied at the radius 0,9D/2 in the weakest direction of the blade.

2.8 Keyless propellers

2.8.1 When it is proposed to use keyless propellers, the fit of the propeller boss to the screwshaft will be specially considered.

2.9 Screwshafts

2.9.1 The diameter d_s at the aft bearing of the screwshaft fitted in conjunction with a solid propeller is to be not less than:

$$d_s = 1{,}08\sqrt[3]{\frac{\sigma_u\,LT^2}{\sigma_o}}\ \text{mm}$$

where

L and T = proposed width and thickness respectively of the propeller blade section at 0,25D/2, in mm
σ_o = specified minimum yield stress of the material of the screwshaft, in N/mm^2 (kgf/mm^2)
σ_u = specified minimum tensile strength of the blade material, in N/mm^2 (kgf/mm^2).

2.9.2 The diameter, d_s at the aft bearing of the screwshaft fitted in conjunction with a controllable pitch propeller is to be not less than:

$$d_s = 1,15 \sqrt[3]{\frac{\sigma_u L T^2}{\sigma_o}} \text{ mm}$$

where

L and T = proposed width and thickness respectively of the propeller blade section at 0,35D/2, in mm

σ_o = specified minimum yield stress of the material of the screwshaft, in N/mm^2 (kgf/mm^2)

σ_u = specified minimum tensile strength of the blade material, in N/mm^2 (kgf/mm^2).

2.9.3 Where the screwshaft diameter as derived by 2.9.1 or 2.9.2 is less than the diameter derived by Ch 6,3.5.1, the latter is to apply.

2.9.4 The shaft may be tapered at the forward end in accordance with Ch 6,3.5.4.

2.10 Intermediate and thrust shafts

2.10.1 The diameters of intermediate shafts and thrust shafts in external bearings are to comply with Ch 6,3.1 and Ch 6,3.4 respectively, except for **Ice Class 1AS FS** ice strengthening where these diameters are to be increased by 10 per cent.

2.11 Reduction gearing

2.11.1 Where gearing is fitted between the engine and the propeller shafting, the gearing is to be in accordance with Chapter 5, and is to be designed to transmit a torque, Y_i, determined by the following formula:

$$Y_i = Y + \frac{M I_h u^2}{I_l + I_h u^2} \text{ kN m (tonne-f m)}$$

where

u = gear ratio = $\dfrac{\text{pinion speed}}{\text{wheel speed}}$

I_h = mass moment of inertia of machinery components rotating at higher speed

I_l = mass moment of inertia of machinery components rotating at lower speed, including propeller with an addition of 30 per cent of entrained water

(I_h and I_l are to be expressed in the same units)

M = ice torque as defined in 2.2

$$Y = 9,55 \frac{P}{R}$$

$$\left(Y = 0,716 \frac{H}{R}\right)$$

P (H) and R are as defined in 2.3.

2.12 Fire pumps in motor ships

2.12.1 In motor ships where clearing steam is not available, fire pumps are to be provided with suctions from the cooling water inlet chest.

■ Section 3
Ice Class 1D and 1E

3.1 General

3.1.1 Where the notation Ice Class **1D** or Ice Class **1E** is desired, the requirements of this Section, in addition to those for open water service, are to be complied with.

3.1.2 For Ice Class **1D** or Ice Class **1E**, the total engine output is to be not less than determined by the following formula:

P = 0,72LB kW

(H = 0,98LB) Hp

where

L = Rule length, in metres, *see* Pt 3, Ch 1,6.1.1

B = moulded breadth of ship, in metres, *see* Pt 3, Ch 1,6.1.3

3.2 Main engine shafting, gearing and propellers

3.2.1 The diameters of the shafting and propeller blade thickness as required by the Rules for open water service are to be increased by the following percentages. No increase in the diameter of crankshafts, thrustshafts or intermediate shafts is required.

Screwshaft, increase in diameter as required by Ch 6,3.5	5%
Propeller, increase in blade thickness at root and at 60 per cent radius as required by Ch 7,3.1	8%
Keyless propeller fitting, increase in mean torque Q as defined in Ch 7,3.2.	15%

3.2.2 The screwshaft may be tapered at the forward end in accordance with Ch 6,3.5.4.

3.3 Minimum propeller blade tip thickness

3.3.1 The tip thickness, t, of the blade at 95 per cent radius is to be not less than that obtained by the following formula:

$$t = 0,14 (T + 57 \sqrt[3]{\frac{430}{\sigma_u}} \text{ mm}$$

$$\left(t = 0,14 (T + 57) \sqrt[3]{\frac{44}{\sigma_u}} \text{ mm}\right)$$

where

T = blade root thickness required by 3.2.1, in mm

σ_u = specified minimum tensile strength of material, in N/mm^2 (kgf/ mm^2).

3.4 Blade edge thickness

3.4.1 The edges of the blades are to be suitably thickened for the operating conditions but are to be not less than 50 per cent of the required tip thickness, t, measured at 1,25 times tip thickness, t, from the edge. For controllable pitch propellers, this requirement need only be applied to the leading edges of the blades.

3.5 Ship-side valves

3.5.1 The sea inlet and overboard discharge valves which are situated at or below the maximum Load Line, are to be provided with low pressure steam or compressed air connection for clearing purposes, *see* Chapter 13.

3.5.2 When steam is not available for clearing, it is recommended that arrangements be made for supplying water for machinery cooling purposes by circulating from ballast tanks(s) of adequate capacity, preferably situated in the double bottom. Such tank(s) must be used only for storage of water ballast or fresh water.

3.6 Cooling water lines

3.6.1 Connections are to be fitted between the cooling water overboard discharge lines and sea inlets for main and/or auxiliary engine cooling water systems so that warm water may be used to assist in maintaining the suction pipes free from ice.

3.6.2 Where the cooling water inlet valves are fitted to a common water box, the connections from the cooling water discharge lines may be led to the water box in a position as near as possible to the inlet valves.

3.7 Fire pumps in motor ships

3.7.1 In motor ships where clearing steam is not available, fire pumps are to be provided with suctions from the main cooling water inlet pipe.

■ *Section 4* Ice Classes 1AS FS(+), 1A FS(+), 1B FS(+) and 1C FS(+)

4.1 Powering of ice strengthened ships

4.1.1 For ships that require additional strengthening in ice the total shaft power installed is to be calculated using the following sections, but is not to be less than required by the Finnish Swedish Ice Class Rules in force at the time of contract.

4.1.2 Ice strengthened ships which are to be considered to have an icebreaking capability are to be able to develop sufficient thrust to permit continuous mode icebreaking at a speed of at least five knots in ice having a thickness equal to the nominal value for the desired Ice Class and a snow cover of at least 0,3 m.

4.1.3 The shaft power necessary to provide an icebreaking capability can be determined by the equation:

$$P_1 = 0{,}736 C_1 C_2 C_3 C_4 \left[240 B h (1 + h + 0{,}035 v^2) + 70 S_c \sqrt{L}\right]$$

$$\left(H_1 = C_1 C_2 C_3 C_4 \left[240 B h (1 + h + 0{,}035 v^2) + 70 S_c \sqrt{L}\right]\right)$$

where

B = moulded breath of ship, in metres, *see* Pt 3, Ch 1,6.1.3

L = Rule length, in metres, *see* Pt 3, Ch 1,6.1.1.

Δ = displacement, in tonnes, *see* Pt 3, Ch 9,7.2.1

$C_1 = \dfrac{1{,}2B}{\sqrt[3]{\Delta}}$, but is not to be taken as less than 1,0

C_2 = 0,9 if the ship is fitted with a controllable pitch propeller, otherwise 1,0

C_3 = 0,9 if the rake of the stem is 45° or less, otherwise 1,0. The product $C_2\, C_3$ is not to be taken as less than 0,85

C_4 = 1,1 if the ship is fitted with a bulbous bow, otherwise 1,0

h = ice thickness

S_c = depth of snow cover

v = ship speed, in knots, when breaking ice of thickness h.

Part 8, Chapter 1
Application

Effective date 1 March 2008

■ *Section 1* Scope

1.1 General

1.1.1 The following requirements are for ships intended for operations in ice and cold conditions.

1.1.2 Guidance on the appropriate requirements and notations is provided in Table 1.1.1.

■ *Section 2* Ice environment

2.1 General

2.1.1 This Section is intended to give assistance on the selection of a suitable ice class notation for the operation of ships in ice-covered regions.

2.1.2 The Owner is to confirm which notation is most suitable for their requirements. Ultimately, the responsibility rests with the master of the ship and their assessment of the ice and temperature conditions at the time.

2.1.3 The documentation supplied to the ship is to contain the ice class notation adopted, any operation limits for the ship and guidance on the type of ice that can be navigated for the nominated ice class.

Table 1.1.1 Ice and cold operations

<table>
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<tr><td rowspan="3">Section 3</td><td rowspan="3">Equipment and systems</td><td rowspan="3">Low temperature operations</td><td>Short duration</td><td>Winterisation C(T)</td></tr>
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<tr><td>Prolonged duration</td><td>Winterisation A(T)</td></tr>
</table>

2.2 Definitions

2.2.1 The World Meteorological Organisation's, WMO, definitions for sea ice thickness are given in Table 1.2.1.

Table 1.2.1 WMO defintion of ice conditions

Ice conditions	Ice thickness
Medium first-year	1,2 m
Thin first-year, second stage	0,7 m
Thin first-year, first stage	0,5 m
Grey-white	0,3 m
Grey	0,15 m

2.2.2 Table 1.2.2 defines the ice classes in relation to the Rules and the equivalent internationally recognized standards.

2.3 Application

2.3.1 The variable nature of ice conditions is such that the average limits of the conditions are not easily defined. However, it is possible to plot the probable limits of the ice flows and the ice edge for each season. *See* Figs. 1.2.1 to 1.2.4, and Table 1.2.3.

2.3.2 Operation with **Ice Class 1C FS** may be possible up to 150 nm inside the 7/10 region shown depending on the severity of the winter. Operation with **Ice Class 1A FS** may be possible up to 150 nm inside the medium first-year ice shown depending on the severity of the winter. Operation up to the multi-year ice is possible most years with **Ice Class 1AS FS**.

Table 1.2.2 Comparison of ice standards

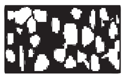
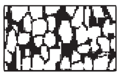
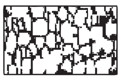
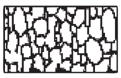
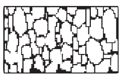
Lloyd's Register class notation	Finnish Swedish Ice Class	Canadian type
Ice Class 1AS FS(+) Ice Class IAS FS	IA Super	A
Ice Class 1A FS(+) Ice Class 1A FS	IA	B
Ice Class 1B FS(+) Ice Class 1B FS	IB	C
Ice Class 1C FS(+) Ice Class 1C FS	IC	D
Ice Class 1D	—	D
Ice Class 1E	—	E

2.3.3 Operation in the region between 7/10 and 1/10 in the ice-covered regions is possible with due care for ships with no ice class. For ships operating for extended periods in these areas, it will be necessary to specify and design for a minimum temperature for the hull materials. To cover all situations for a non-ice class ship, the material requirements of *The Provisional Rules for the Winterisation of Ships* are recommended.

2.4 Ice Class notations

2.4.1 Where the requirements of Chapter 2 are complied with, the ship will be eligible for a special features notation as defined in Pt 1, Ch 2,2.1.9, *see also* Table 1.1.1.

Table 1.2.3 Concentration of ice

Free ice	 0/10		
Open water	 <1/10		
Very open drift	 1/10	 2/10	 3/10
Open drift	 4/10	 5/10	 6/10
Close pack/drift	 7/10	 8/10	
Very close pack	 9/10		
Very close pack	 9+/10		
Compact/consolidated ice	 10/10		

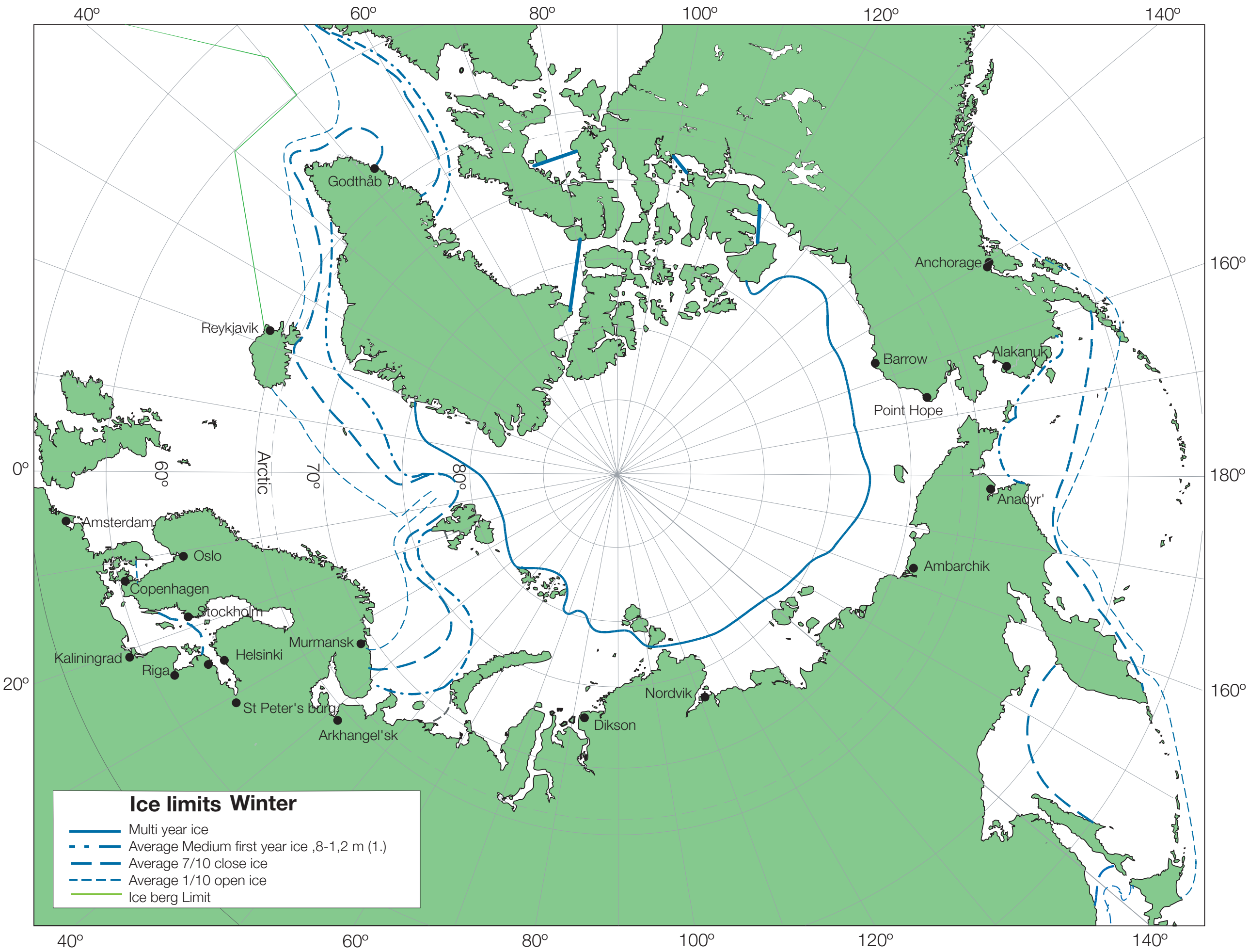


Fig. 1.2.1 Ice Limits for the Arctic Winter

2.5 National Authority requirements

2.5.1 Certain areas of operation may require compliance or demonstration of equivalence with National Authority requirements. Table 1.2.2 gives the equivalence of National Authority requirements.

2.5.2 The standards of ice strengthening required by the Rules have been accepted by the Finnish and Swedish Boards of Navigation as being such as to warrant assignment of the Ice Classes given in Table 1.2.2.

2.5.3 Ships intending to navigate in the Canadian Arctic must comply with the *Canadian Arctic Shipping Pollution Prevention Regulations established by the Consolidated Regulations of Canada, 1978, Chapter 353*, in respect of which Lloyd's Register is authorised to issue Arctic Pollution Prevention Certificates.

2.5.4 The Canadian Arctic areas have been divided into zones relative to the severity of the ice conditions experienced and, in addition to geographic boundaries, each zone has seasonal limits affecting the necessary ice class notation required to permit operations at a particular time of year. It is the responsibility of the Owner to determine which notation is most suitable for their requirements.

2.5.5 The Canadian Authorities recognize that in the period November 6 to July 31 and any extension to that period declared by the Canadian Coast Guard, oil and bulk chemical tankers which qualify for Canadian Type A, B, C and D as indicated in Table 1.2.2 are suitable for operating in designated ice control zones within Canadian waters, off the east coast of Canada south of 60° north latitude. For all Type E tankers operating in this zone during the specified period, the Canadian Authorities will require either additional hull strength in way of the forward wing cargo tanks port and starboard, or the level of oil or chemical in these tanks to be not higher than one metre below the waterline of the ship in her condition of transit. Where the latter arrangement is adopted, the effect on longitudinal strength is to be considered.

2.6 Ice conditions

2.6.1 Charts and images for the current and recent ice conditions in all areas of the world plus information on icebergs can be found from the National Ice Centre on the world wide web at:

www.natice.noaa.gov

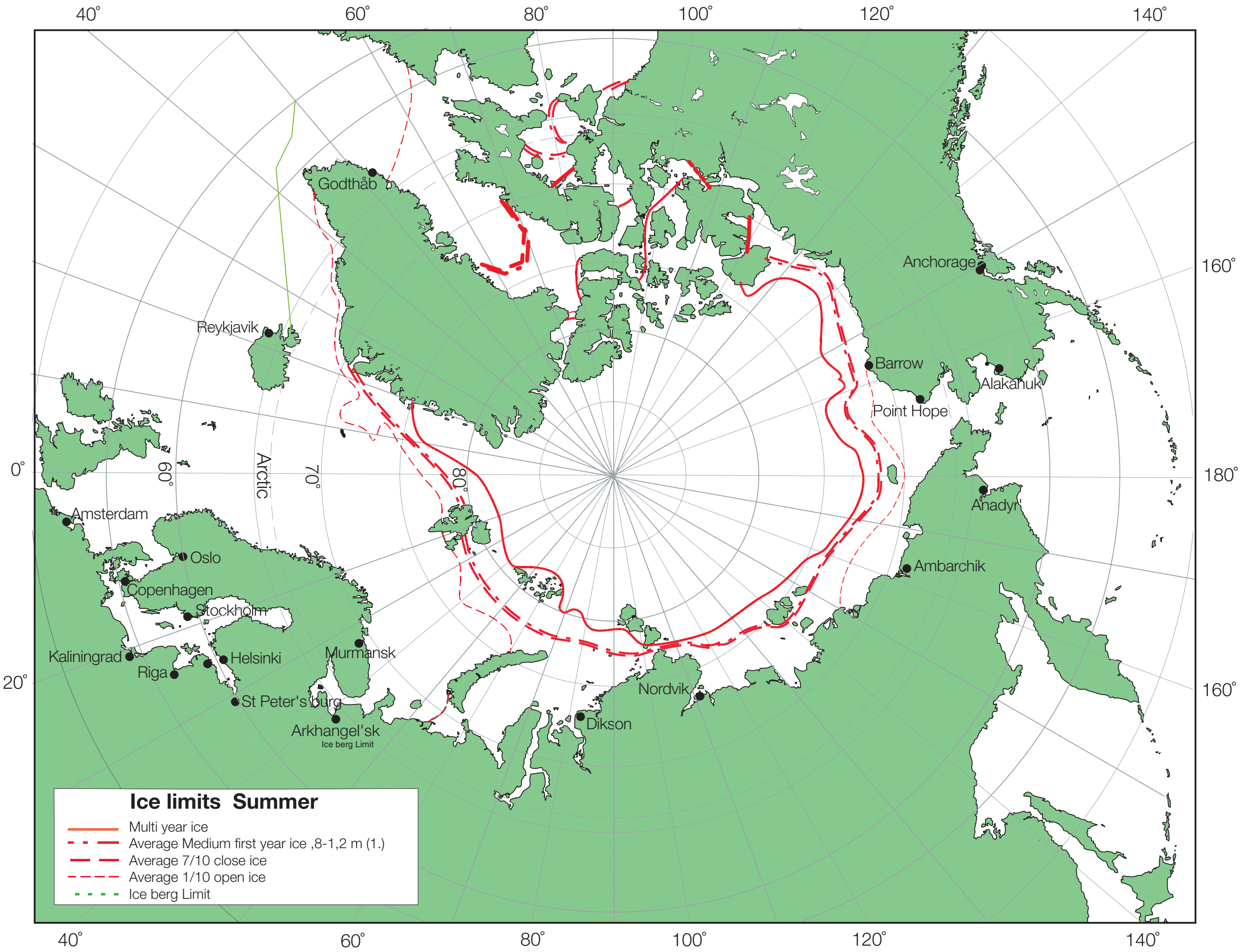


Fig. 1.2.2 Ice Limits for the Arctic Summer

2.6.2 Daily ice information and consultation is available from the Canadian ice service which is part of the Canadian department of the environment. Their web site can be found at:

www.ice-glaces.ec.gc.ca

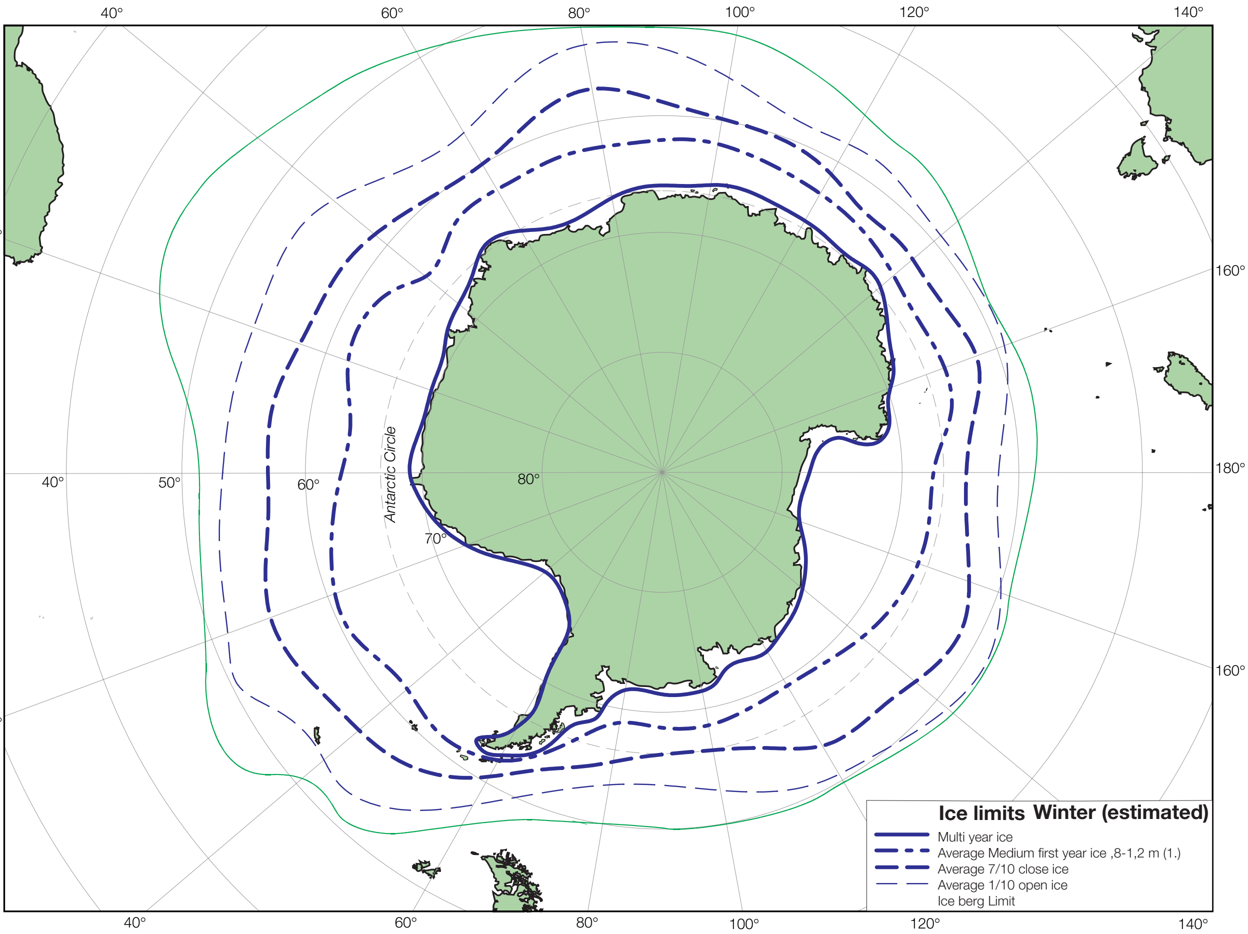


Fig. 1.2.3 Ice Limits for the Antarctic Winter

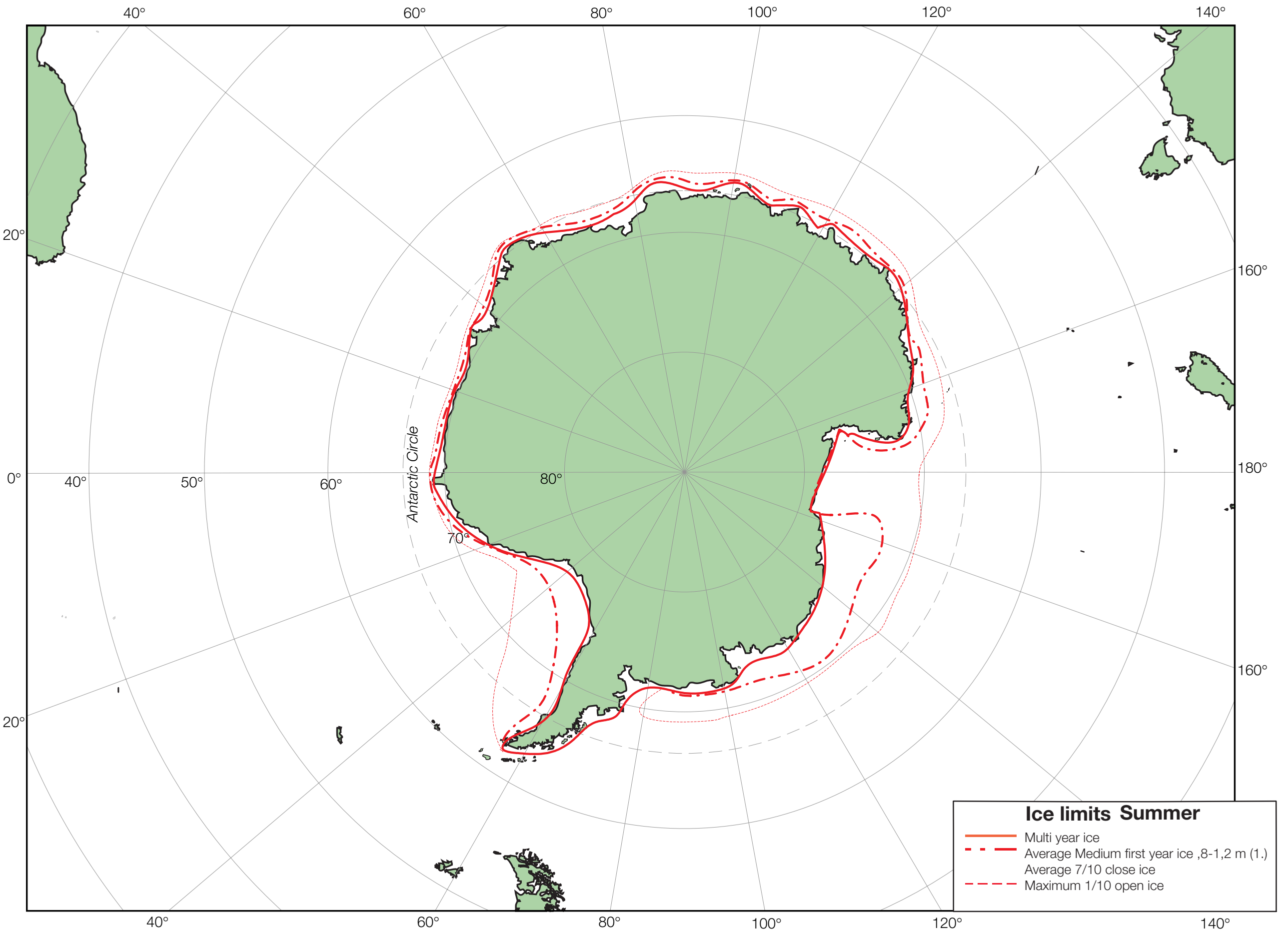


Fig. 1.2.4 Ice Limits for the Antarctic Summer

Section 3
Air environment

3.1 Air temperature

3.1.1 For ships intended to operate in cold regions, the temperature on exposed surfaces is to be considered. *See The Provisional Rules for the Winterisation of Ships*.

3.1.2 The average external design air temperature is to be taken as the lowest mean daily average air temperature in the area of operation:

where

Mean = statistical mean over a minimum of 20 years
Average = average during one day and one night
Lowest = lowest during the year
MDHT = Mean Daily High Temperature
MDAT = Mean Daily Average Temperature
MDLT = Mean Daily Low Temperature

Fig. 1.3.1 shows the definition graphically.

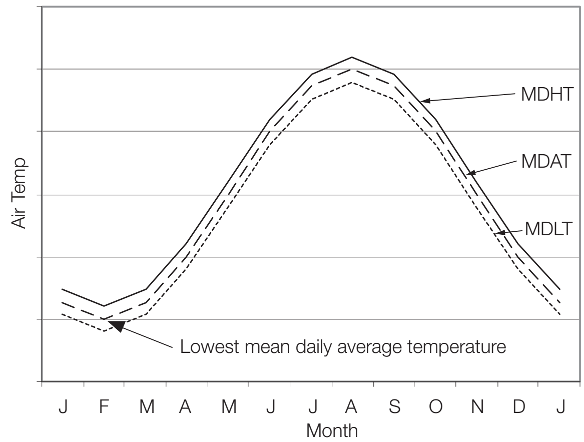


Fig. 1.3.1 Air temperature

3.1.3 The lowest external design air temperature is to be taken as the lowest mean daily lowest air temperature in the area of operation. Where reliable environmental records for contemplated operational areas exist, the lowest external design air temperature may be obtained after the exclusions of all recorded values having a probability of occurrence of less than 3 per cent.

3.1.4 Lowest mean daily average air temperatures for the Arctic and Antarctic are provided in Figs. 1.3.2 and 1.3.3.

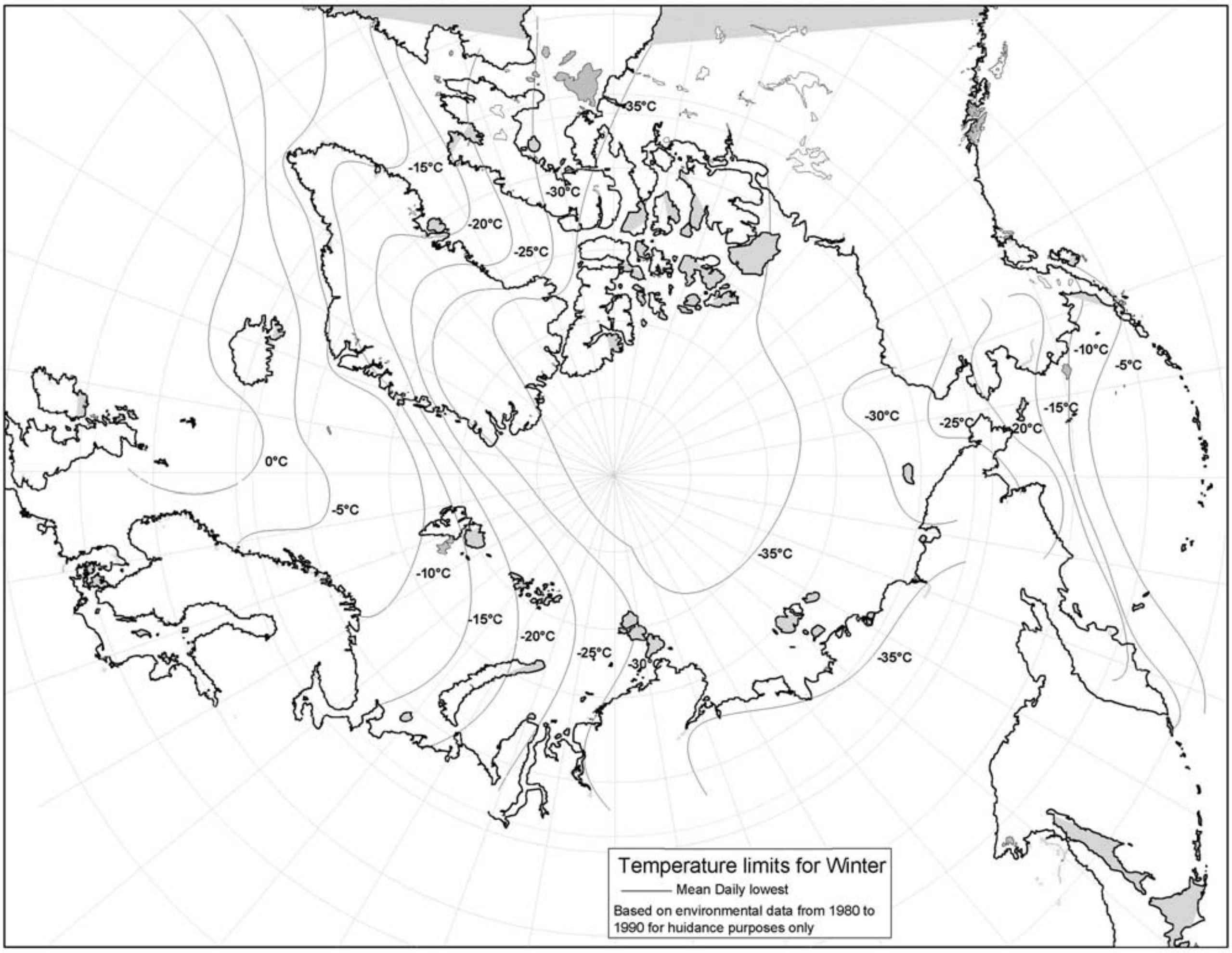


Fig. 1.3.2 Lowest mean daily air temperatures for the Arctic

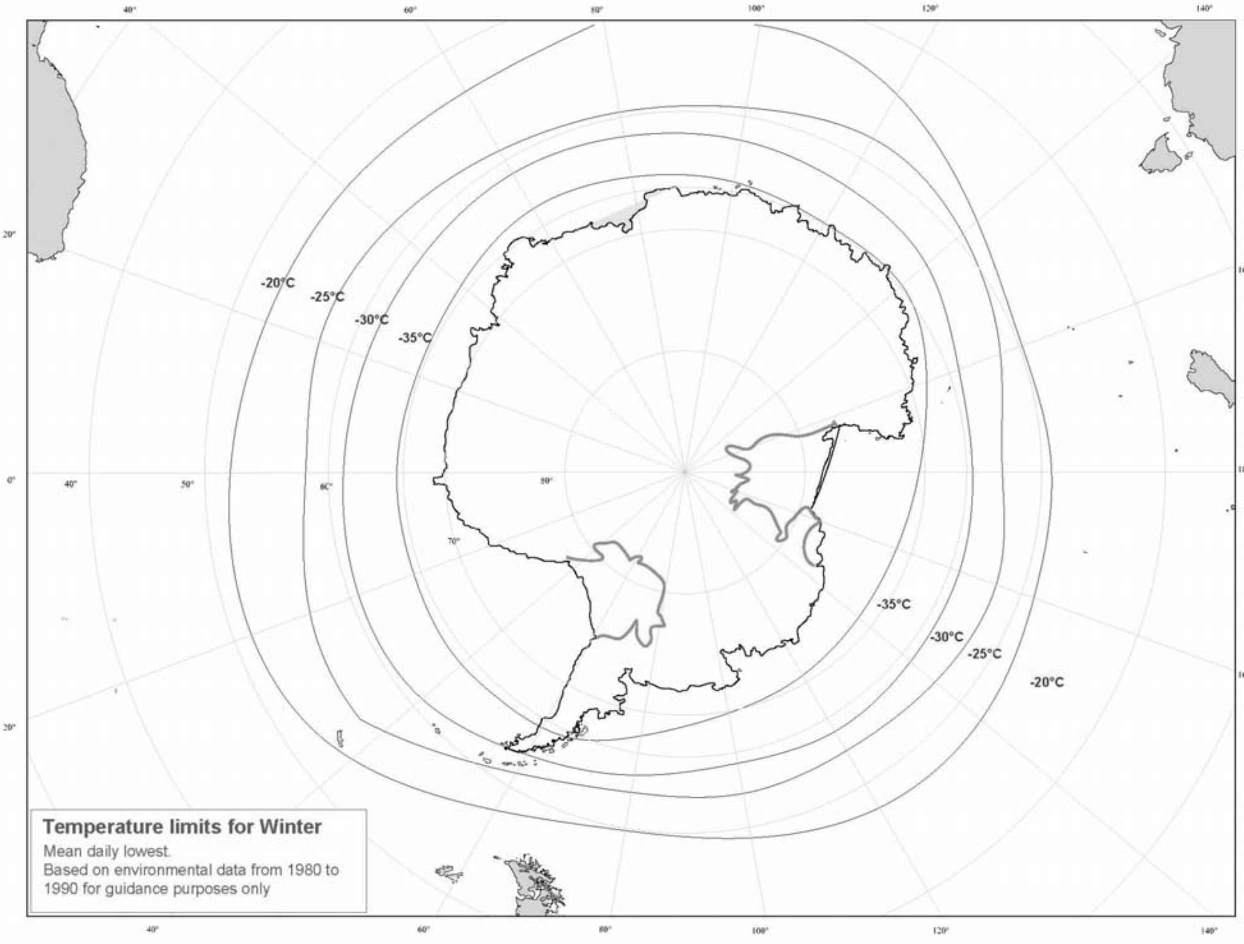


Fig. 1.3.3 Lowest mean daily air temperatures for the Antarctic

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■ *Section 4*
Icing environment

4.1 Ice accretion

4.1.1 For ships intended to operate in cold regions, the build up of ice on exposed surfaces is to be considered. *See The Provisional Rules for the Winterisation of Ships*.

4.1.2 Icing is to be considered for vessels operating in the following areas, *see* Figs. 1.4.1 and 1.4.2.

- The area north of latitude 65°30'N, between longitude 28°W and the West coast of Iceland; north of the north coast of Iceland; north of the rhumb line running from latitude 66°N, longitude 15°W to latitude 73°30'N, longitude 15°E, north of latitude 73°30'N between longitude 15°E and 35°E, and east of longitude 35°E, as well as north of latitude 56°N in the Baltic Sea.
- The area north of latitude 43°N bounded in the west by the North American coast and the east by the rhumb line running from latitude 43°N, longitude 48°W to latitude 63°N, longitude 28°W and thence along longitude 28°W.
- All sea areas north of the North American continent west of the areas defined in subparagraphs above.
- The Bering and Okhotsk Seas and the Tartary Strait during the icing season.
- South of latitude 60°S.

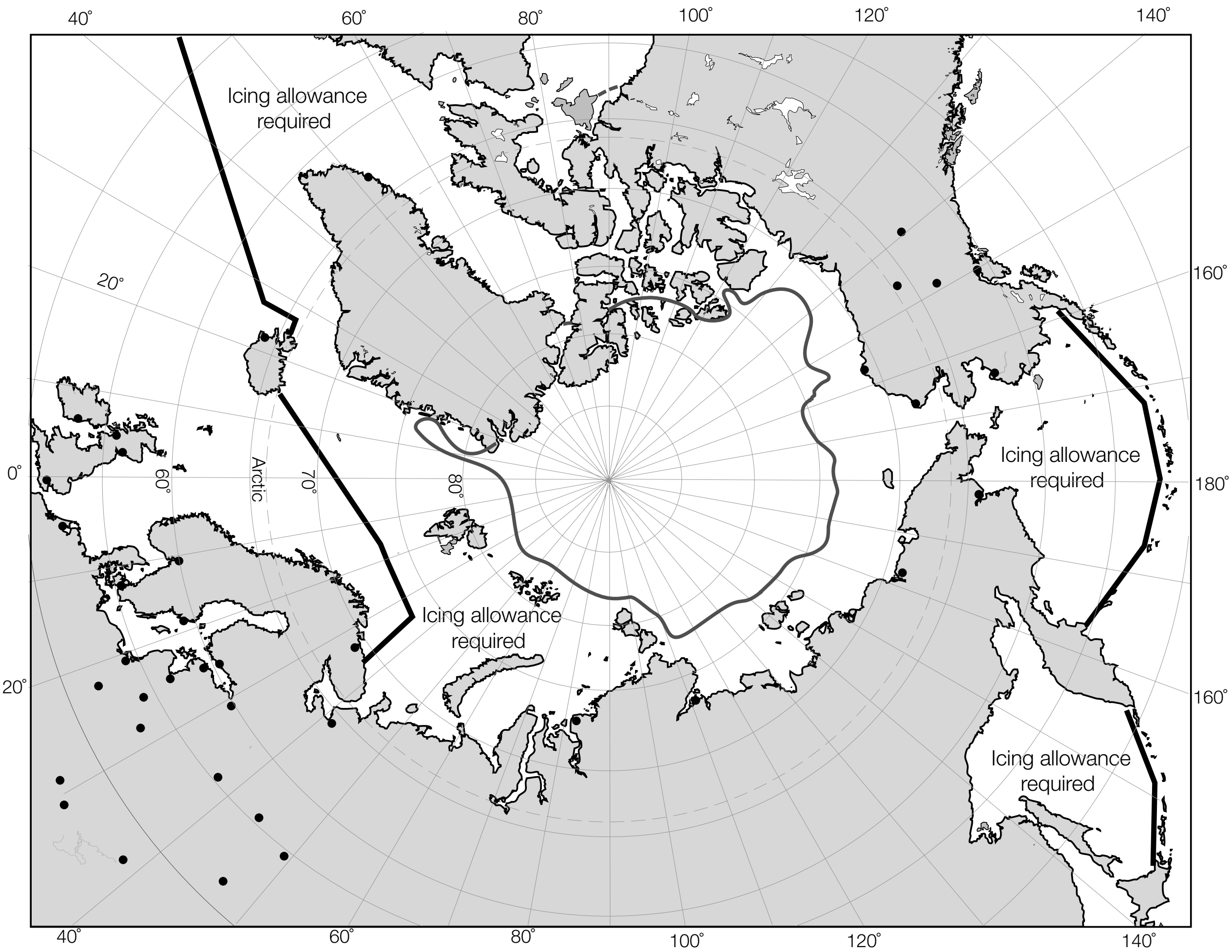


Fig. 1.4.1 Ice accretion limits for the Arctic

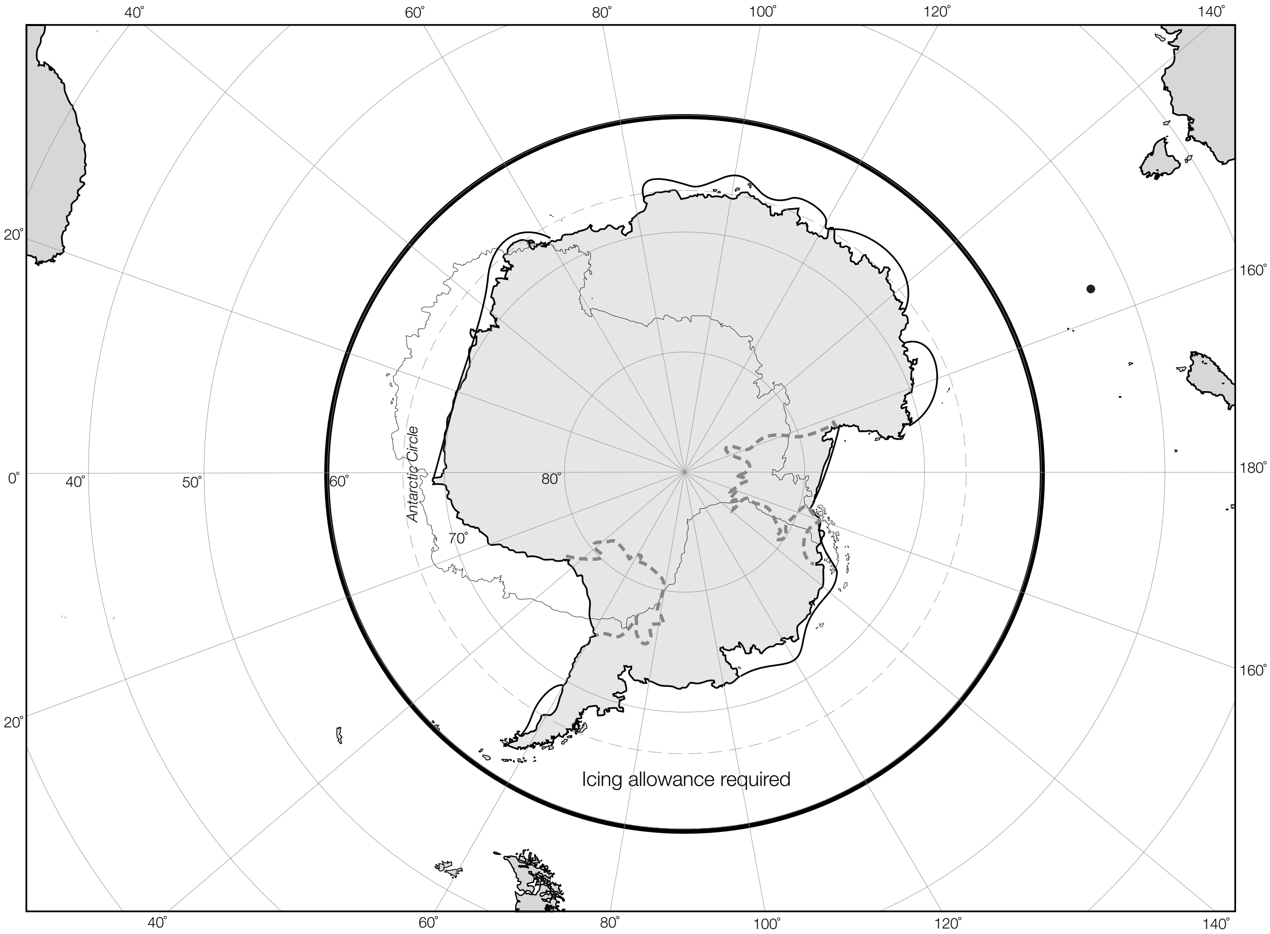


Fig. 1.4.2 Ice accretion limits for the Antarctic

Part 8, Chapter 2
Ice Operations – Ice Class

Effective date 1 March 2008

■ *Section 1* Strengthening requirements for navigation in ice – Application of requirements

1.1 Additional strengthening

1.1.1 Where additional strengthening is fitted in accordance with the requirements given in this Chapter, an appropriate special features notation will be assigned. It is the responsibility of the Owner to determine which notation is most suitable for his requirements.

1.1.2 Where a special features notation is desired, the ship is to comply with the requirements of the applicable Sections, in addition to those for sea-going service, so far as they are applicable.

1.2 Application for light ice conditions

1.2.1 The requirements for **Ice Class IE** are for ships with length less than 150 m and are intended to navigate in very light first-year ice conditions, such as in brash ice and small ice pieces. The requirements of Sections 4 and 5 are to be complied with.

1.2.2 The requirements for **Ice Class 1D** are for ships intended to navigate in light first-year ice conditions. The requirements for strengthening the forward region, the rudder and steering arrangements for **Ice Class 1C FS** are applicable.

1.3 Application for first-year ice conditions

1.3.1 Ships that comply with the requirements of the Finnish Swedish Ice Class Rules and Sections 6 and 7, for **Ice Class IA Super**, **IA**, **IB** and **IC** may be assigned the corresponding notations **Ice Class 1AS FS**, **Ice Class 1A FS**, **Ice Class 1B FS** or **Ice Class 1C FS**. The *Finnish Swedish Ice Class Rules* may be obtained from the following website:
www.fma.fi

1.3.2 For ships where the ice class notation **Ice Class 1AS FS(+)**, **Ice Class 1A FS(+)**, **Ice Class 1B FS(+)** or **Ice Class 1C FS(+)** is requested, the requirements of the *Finnish Swedish Ice Class Rules*, and Sections 8 and 9 are to be complied with.

1.4 Application for multi-year ice conditions

1.4.1 The requirements for strengthening for navigation in ice, as given in Sections 10 and 11, are intended for ships operating in multi-year ice in Arctic or Antarctic ice conditions under their own power and constructed of steel, except icebreakers (*see* 1.5.1).

1.4.2 Ships that comply with Sections 10 and 11 can be considered for a Polar Class (PC) notation as listed in Table 2.1.1. The requirements of Sections 10 and 11 are in addition to the open water requirements. If the hull and machinery are constructed such as to comply with the requirements of different polar classes, then both the hull and machinery are to be assigned the lower of these classes in the classification certificate. Compliance of the hull or machinery with the requirements of a higher polar class is also to be indicated in the classification certificate or an appendix thereto.

Table 2.1.1 Polar class descriptions

Polar Class	Ice description (based on WMO Sea Ice Nomenclature)
Ice Class PC 1	Year-round operation in all Polar waters
Ice Class PC 2	Year-round operation in moderate multi-year ice conditions
Ice Class PC 3	Year-round operation in second-year ice which may include multi-year ice inclusions
Ice Class PC 4	Year-round operation in thick first-year ice which may include old ice inclusions
Ice Class PC 5	Year-round operation in medium first-year ice which may include old ice inclusions
Ice Class PC 6	Summer/autumn operation in medium first-year ice which may include old ice inclusions
Ice Class PC 7	Summer/autumn operation in thin first-year ice which may include old ice inclusions

1.4.3 The Polar Class (PC) notations and descriptions are given in Table 2.1.1. It is the responsibility of the Owner to select an appropriate Polar Class. The descriptions in Table 2.1.1 are intended to guide owners, designers and administrations in selecting an appropriate Polar Class to match the requirements for the ship with its intended voyage or service.

1.4.4 The Polar Class notation is used throughout Sections 10 and 11 to convey the differences between classes with respect to operational capability and strength.

1.5 Icebreakers

1.5.1 Sea-going ships specially designed for icebreaking duties will be assigned the ship type notation 'Icebreaker' in addition to the special features notation appropriate to the degree of ice strengthening provided. 'Icebreaker' refers to any ship having an operational profile that includes escort or ice management functions, having powering and dimensions that allow it to undertake aggressive operations in ice-covered waters, and having a class certificate endorsed with this notation.

■ Section 2
General hull requirements for navigation in ice – All ice classes

2.1 General

2.1.1 In addition to the requirements of the *Finnish Swedish Ice Class Rules*, the following Sections are to be complied with for **Ice Class 1AS FS**, **Ice Class 1A FS**, **Ice Class 1B FS**, **Ice Class 1C FS** and **Ice Class 1D**, where applicable. Alternative arrangements to attain similar performance will be specially considered.

2.1.2 The ballast capacity of the ship is to be sufficient to give adequate propeller immersion in all ice navigating conditions without trimming the ship in such a manner that the actual waterline at the bow is below the ice light waterline.

2.1.3 Fresh water and sea water ballast tanks situated above the design ballast waterline and adjacent to the shell, which are intended to be used in ice and cold navigating conditions, are to be provided with means to prevent freezing. These measures are to provide protection so that pumping water will not cause a vacuum beneath a layer of ice across the top of the water in the tank, and, are to protect against structural and systems damage from ice expansion. The following tank heating requirements are to be complied with:

(a) For **Ice Class 1C**, **Ice Class 1D** and **Ice Class 1E**:
Tanks entirely above the waterline are to be provided with heating coils or continuous circulation.
Tanks partially below the waterline are to be provided with heating coils, continuous circulation or air bubbling.

(b) For all other **Ice Classes**:
All tanks entirely above and partially below the waterline are to be provided with heating coils.

2.1.4 These Rules are formulated for both transverse and longitudinal framing systems but it is recommended that, whenever practicable, transverse framing is selected.

2.1.5 These Rules assume that when approaching ice infested waters, the ship's speed will be reduced appropriately. The vertical extent of ice strengthening for ships intended to operate at speeds exceeding 15 knots in areas containing isolated ice floes will be specially considered.

2.1.6 An icebreaking ship is to have a hull form at the fore end adapted to break ice effectively. It is recommended that bulbous bows are not fitted to **Ice Class 1AS** ships.

2.1.7 The stern of an icebreaking ship is to have a form such that broken ice is effectively displaced.

2.1.8 Where it is desired to make provision for short tow operations, the bow area is to be suitably reinforced. Similarly, icebreakers may require local reinforcement in way of the stern fork.

2.1.9 The vertical extent of the ice strengthening is related to the ice light and ice load waterlines, which are defined in 2.2. The maximum and minimum Ice Class draughts at both the fore and aft ends will be stated on the Class Certificate. In addition, the installed and required minimum engine output, *see* Section 7, will be stated on the Class Certificate.

2.2 Definitions

2.2.1 The upper and lower ice waterlines upon which the design of the vessel has been based is to be indicated in the classification certificate. The upper ice waterline (UIWL) is to be defined by the maximum draughts fore, amidships and aft. The lower ice waterline (LIWL) is to be defined by the minimum draughts fore, amidships and aft.

2.2.2 The lower ice waterline is to be determined with due regard to the vessel's ice-going capability in the ballast loading conditions (e.g. propeller submergence).

2.2.3 The upper ice waterline (UIWL) and lower ice waterline (LIWL) are to be indicated on the plans. For navigation in certain geographical areas, the relevant National Authority may require the maximum Ice Class draught to be marked on the ship in a specified manner.

2.2.4 **Displacement** Δ is the displacement at the upper ice waterline (UIWL) when floating in water having a relative density of 1,0. For first-year ice class Rules, the displacement is in tonnes. For multi-year ice class Rules, the displacement is in kilo tonnes.

2.2.5 **Shaft power**, P_0 , is the maximum propulsion shaft power, in kW, for which the machinery is to be classed.

■ Section 3
General machinery requirements for navigation in ice – All ice classes

3.1 Materials for shafting

3.1.1 All components of the main propulsion system are to be of steel or other approved ductile material.

3.1.2 For screwshafts in ships intended for the notation **Ice Class 1AS FS** or **Ice Class 1A FS** and where the connection between the propeller and the screwshaft is by means of a key, Charpy impact tests are to be made in accordance with the requirements of Ch 5,3.4.12 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.2 Materials for propellers

3.2.1 Propellers and propeller blades are to be of cast steel or copper alloys and are to be manufactured, tested and certified in accordance with Ch 4,1, Ch 4,5 and Ch 9,1 of the Rules for Materials respectively.

3.2.2 For steel propellers, the elongation of the material used is to be not less than 19 per cent for a test piece length of 5*d*. Charpy impact tests are to be carried out in accordance with the requirements of the Rules for Materials.

3.2.3 Cast steel load transmitting components of controllable pitch mechanisms are to be manufactured, tested and certified in accordance with the requirements of Ch 4,5 of the Rules for Materials.

3.2.4 Forged steel load transmitting components of controllable pitch propellers are to be manufactured, tested, and certified in accordance with Ch 5,1 and Ch 5,2 of the Rules for Materials. Impact tests are to be carried out at minus 10°C and the average energy value is to be not less than 27 J.

3.2.5 Spheroidal cast iron load transmitting-components of controllable-pitch mechanisms are to be manufactured, tested and certified in accordance with the requirements of Table 7.3.2 in Ch 7,3 of the Rules for Materials.

3.3 Ship-side valves

3.3.1 The sea inlet and overboard discharge valves which are situated at or below the maximum Load Line, are to be provided with low pressure steam or compressed air connection for clearing purposes, *see* Pt 5, Ch 13.

3.3.2 When steam is not available for clearing, it is recommended that arrangements be made for supplying water for machinery cooling purposes by circulating from ballast tanks(s) of adequate capacity, preferably situated in the double bottom. Such tank(s) must be used only for storage of water ballast or fresh water.

3.4 Fire pumps in motor ships

3.4.1 In motor ships where clearing steam is not available, fire pumps are to be provided with suctions from a suitable sea water inlet which is maintained ice-free at all times.

3.4.2 At least one of the fire pumps is to be connected to a sea chest which is provided with de-icing arrangements.

■ *Section 4*
Hull requirements for light ice conditions – Ice classes 1D and 1E

4.1 Ice Class 1D

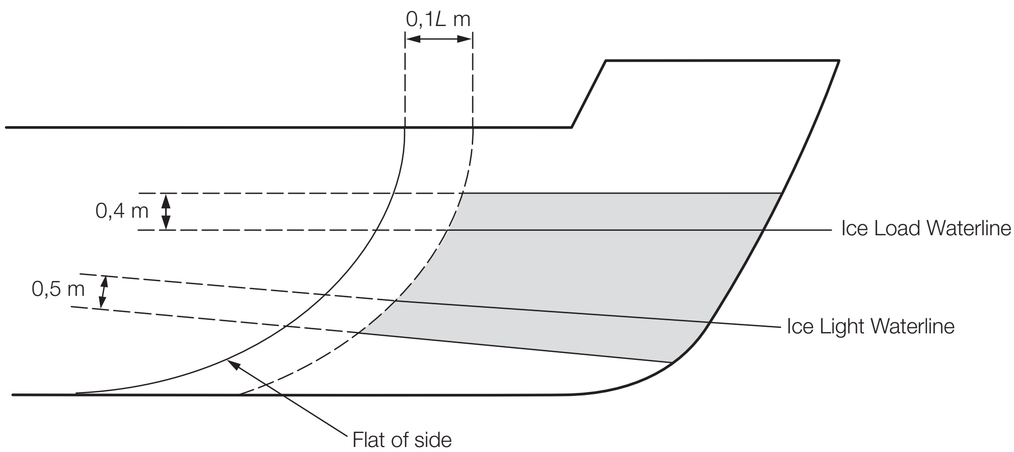
4.1.1 The requirements for strengthening the forward region for **Ice Class 1C FS** are applicable. *See* Section 6.

4.2 Ice Class 1E – General

4.2.1 These requirements apply to ships with length less than 150 m and which are intended to operate in very light first-year ice conditions. Where additional strengthening is fitted in accordance with the requirements of this sub-Section, the notation **Ice Class 1E** will be assigned.

4.2.2 For longitudinally framed ships, the scantlings of shell plating and framing are to comply with the requirements of **Ice Class 1C FS** using 0,9 times the ice pressure. The requirements for shell plating need only be applied in the region shown in Fig. 2.4.1. The requirements for framing need only be applied forward of the flat of side.

4.2.3 For transversely framed ships, the requirements of 4.3 to 4.7 are to be applied.



Ice Load Waterline and Ice Light Waterline are defined in 7.2
L, as defined in Ch 1,6.1

Fig. 2.4.1 Extent of application of plating requirements

4.2.4 Where the structural requirements of **Ice Class 1C FS** give lesser scantlings than the requirements of this sub-Section, the lesser scantlings may be applied.

4.3 Shell plating

4.3.1 The shell plating thickness within the region shown in Fig. 2.4.1 is not to be less than:

$$t = 21{,}75s\sqrt{k\left(\frac{BL^2}{110000}+1\right)\left(1{,}3-\frac{4{,}2}{(0{,}26\,/\,s+1{,}8)^2}\right)}+2 \text{ mm}$$

where

s = spacing of main frames, in metres

L and B = are defined in Pt 3, Ch 1,6.1

k = is defined in Pt 3, Ch 2,1.2.

4.4 Transverse framing

4.4.1 The section modulus of main frames forward of the flat of side is not to be less than:

$$z = 6{,}08slk\left(\frac{BL^2}{140000}+1{,}23\right)\left(7-\frac{1}{2l}\right) \text{ cm}^3$$

but need not be taken as greater than:

$z = s\,L\,T$

where

s = spacing of main frames, in metres

l = span, in metres

L and B = are defined in Pt 3, Ch 1,6.1

k = is defined in Pt 3, Ch 2,1.2

4.4.2 Intermediate ice frames are to be fitted in the region forward of the flat of side and are to extend from 0,62 m above the upper ice waterline to 1 m below the lower ice waterline.

4.4.3 Intermediate ice frames aft of the collision bulkhead are to have a section modulus not less than 65 per cent of that given in 4.4.1.

4.4.4 Intermediate ice frames forward of the collision bulkhead are to have a section modulus not less than 40 per cent of that given in 4.4.1.

4.5 Primary longitudinal members supporting ice frames

4.5.1 Forward of the collision bulkhead, in single deck ships, an ice stringer is to be fitted approximately 0,25 m below the upper ice waterline and is to have scantlings in accordance with Table 5.4.4 in Pt 3, Ch 5.

4.5.2 Aft of the collision bulkhead a series of tripping brackets are to be fitted at each main and intermediate frame at the same level as the ice stringer to a distance 0,1L aft of the flat of side.

4.6 Stern frame and rudder

4.6.1 The rudder and stern frame scantlings are to be in accordance with 6.5. However, the ship's speed need not be taken as greater than 14 knots. The hull form factor and the rudder profile coefficients are to be taken as 1,0.

4.7 Weld connections

4.7.1 Weld connections to the shell plating forward of the collision bulkhead are to be double continuous.

■ *Section 5*
Machinery requirements for light ice conditions – Ice Classes 1D and 1E

5.1 General

5.1.1 Where the notation **Ice Class 1D** or **Ice Class 1E** is desired, the requirements of this Section, in addition to those for open water service, are to be complied with.

5.1.2 The requirements need not be taken as greater than those for **Ice Class 1C FS**.

5.2 Engine power

5.2.1 The total engine output is to be not less than determined by the following formula:

$P = 0{,}72LB$ kW

where

L = Rule length, in metres, *see* Pt 3, Ch 1,6.1.1

B = moulded breadth of ship, in metres, *see* Pt 3, Ch 1,6.1.3.

5.3 Main engine shafting and propellers

5.3.1 The diameters of the shafting and propeller blade thickness as required by the Rules for open water service are to be increased by the percentages as given in Table 2.5.1. No increase in the diameter of crankshafts, thrustshafts or intermediate shafts is required.

Table 2.5.1 Increase for main engine shafting and propellers

Screwshaft, increase in diameter as required by Pt 5, Ch 6,3.5	5%
Propeller, increase in blade thickness at root and at 60 per cent radius as required by Pt 5 Ch 7,3.1	8%
Keyless propeller fitting, increase in mean torque Q as defined in Pt 5, Ch 7,3.2	15%

5.3.2 The screwshaft may be tapered at the forward end in accordance with Pt 5, Ch 6,3.5.3 and Pt 5, Ch 6,3.5.4 subject to the increase in diameter of 5 per cent as required by 5.3.1.

5.4 Minimum propeller blade tip thickness

5.4.1 The tip thickness, t, of the blade at 95 per cent radius is to be not less than that obtained by the following formula:

$$t = 0{,}14\,(T + 57)\sqrt[3]{\frac{430}{\sigma_u}} \text{ mm}$$

where

T = blade root thickness required by 5.2.1, in mm

σ_u = specified minimum tensile strength of material, in N/mm^2.

5.5 Blade edge thickness

5.5.1 The edges of the blades are to be suitably thickened for the operating conditions but are to be not less than 50 per cent of the required tip thickness, t, measured at 1,25 times tip thickness, t, from the edge. For controllable pitch propellers, this requirement need only be applied to the leading edges of the blades.

5.6 Cooling water lines

5.6.1 Connections are to be fitted between the cooling water overboard discharge lines and sea inlets for main and/or auxiliary engine cooling water systems so that warm water may be used to assist in maintaining the suction pipes free from ice.

5.6.2 Where the cooling water inlet valves are fitted to a common water box, the connections from the cooling water discharge lines may be led to the water box in a position as near as possible to the inlet valves.

■ *Section 6*
Hull requirements for first-year ice conditions – Ice classes 1AS FS, 1A FS, 1B FS and 1C FS

6.1 Framing - General requirements

6.1.1 Where a frame intersects a boundary between two of the hull regions the scantling requirements applicable will be those for the forward region if the forward midship boundary is intersected or for the midship region if the aft midship boundary is intersected.

6.1.2 The effective weld area attaching ice frames to primary members is not to be less than the shear area for the frames.

6.2 Primary longitudinal members supporting transverse ice framing

6.2.1 The webs of primary longitudinal members supporting transverse ice frames are to be stiffened and connected to the main or intermediate frames so that the distance, r, between such stiffening is not to be greater than given according to the following formula:

$$r = \sqrt{\frac{291 t^3}{\alpha_o\, y^2}} \text{ mm}$$

where

t = thickness, in mm, of the primary longitudinal member adjacent to the shell plating

α_o = longitudinal distribution factor as given in Table 2.6.1

y = (a) Forward region

$y = 0{,}653 + 3{,}217\sqrt{P_0\,\Delta} \times 10^{-5}$

$y = 0{,}876 + 9{,}908\sqrt{P_0\,\Delta} \times 10^{-6}$

or

$y = 1{,}0$, whichever is the least

= (b) Midship and aft regions

$y = 0{,}653 + 9{,}908\sqrt{P_0\,\Delta} \times 10^{-6}$

or $y = 1{,}0$, whichever is the least

P_0 and Δ = are as defined in 2.2.

Table 2.6.1 Longitudinal distribution factor α_o

Ice Class	α_o		
	Forward	Midship	Aft
1AS FS	1,00	0,98	0,89
1A FS	0,87	0,75	0,64
1B FS	0,78	0,64	0,51
1C FS	0,68	0,53	0,37
1D	0,68	–	–

6.2.2 The minimum thickness of the web plating of longitudinal primary members is to comply with the requirements of Pt 3, Ch 10,4.

6.3 Stem

6.3.1 The stem is to be made of rolled, cast or forged steel or of shaped steel plates. A sharp edged stem, as shown in Fig. 2.6.1 improves the manoeuvrability of the ship in ice.

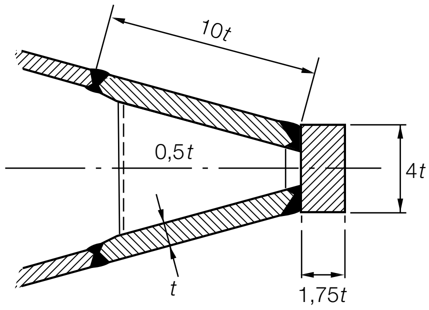


Fig. 2.6.1 A sharp edged stem

6.3.2 The section modulus of the stem in the fore and aft direction is not to be less than determined in accordance with the following formula:

$Z = 1500 (\alpha_O \gamma^2)^{3/2}$ cm^3

where

α_O = longitudinal distribution factor for the forward region as given in Table 2.6.1

γ = is defined in 6.5.2.

6.3.3 The dimensions of a welded stem constructed as shown in Fig. 2.6.1 are to be determined in accordance with the following formula:

$t = 31 \sqrt{\alpha_O \gamma^2}$ mm

where

t = thickness of the side plates, in mm.

6.3.4 In bulbous bow constructions, the extent of plating below the Ice Light Waterline should be such as to cover that part of the bulb forward of the vertical line originating at the intersection of the Ice Light Waterline and the stem contour at the centreline. A suitably tapered transition piece should be arranged between the reinforced stem plating and keel. However, in no case should the reinforced stem plating extend vertically below the Ice Light Waterline for less than 750 mm. The adjacent strake to the reinforced shaped stem plating of the bulb should be in accordance with the requirements for shell plating.

6.3.5 Where in the ice belt region the radius of the stem or bulb front plating is large, one or more vertical stiffeners are to be fitted in order to meet the section modulus requirement of 6.3.2. In addition, vertical ring stiffening will be required for the bulb.

6.3.6 The dimensions of the stem may be tapered to the requirements of Pt 3, Ch 5,3.3 at the upper deck. The connections of the shell plating to the stem are to be flush.

6.4 Stern

6.4.1 Where the screwshaft diameter exceeds the Rule diameter, the propeller post is to be correspondingly strengthened, *see* Pt 3, Ch 6,7.

6.5 Rudder and steering arrangements

6.5.1 Rudder scantlings, posts, rudder horns, solepieces, rudder stocks, steering engine and pintles are to be dimensioned in accordance with Pt 3, Ch 6 and 13 as appropriate. The speed used in the calculations is to be the maximum service speed or that given in Table 2.6.2, whichever is the greater. When used in association with the speed given in Table 2.6.2, the hull form factor and the rudder profile coefficients are to be taken as 1,0.

Table 2.6.2 Minimum speed

Ice Class	Minimum speed, in knots
1AS FS	20
1A FS	18
1B FS	16
1C FS	14
1D	14

6.5.2 For double plate rudders, the minimum thickness of plating and horizontal and vertical webs in the main ice belt zone is to be determined as for shell plating in the aft region. For the horizontal and vertical webs, the corrosion-abrasion increment, c, need not be added. For **Ice Class 1D**, the minimum thickness of plating and webs, of double plate rudders and the extent of application are to be determined as for those in **Ice Class 1C FS**.

6.5.3 Where an ice class notation is included in the class of a ship, the nozzle construction requirements, as defined in Table 13.3.1 in Pt 3, Ch 13, are to be upgraded to include abrasion allowance as follows:

Ice Class	Thickness increment
1AS FS	5 mm
1A FS	4 mm
1B FS	3 mm
1C FS	2 mm
1D	2 mm

However, the thickness of the shroud plating is not to be less than the shell plating for the aft region taking frame spacing s in the formula as 500 mm.

6.5.4 The scantlings of the stock, pintles, gudgeon and solepiece associated with the nozzle are to be increased on the basis given in 6.5.1. However, the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as half the speed given in Table 2.6.3 or the actual astern speed, whichever is the greater.

6.5.5 Nozzles with articulated flaps will be subject to special consideration.

6.5.6 For the Ice Classes **1AS FS** and **1A FS**, the rudder stock and the upper edge of the rudder shall be protected against ice pressure by an ice knife or equivalent means. The ice knife is to extend down to the ice light waterline; this requirement may be waived where this would lead to impracticable ice knifes, e.g. for ships with large draught variations.

6.5.7 For the Ice Classes **1AS FS** and **1A FS**, due regard is to be paid to the excessive load caused by the rudder being forced out of the midship position when backing into an ice ridge. When vessels are intended to operate with significant time in astern operation, then the hull strength is to be based on the method used in the forward region; however, due consideration may be given to the anticipated power in this mode of operation.

6.5.8 Relief valves for hydraulic pressure are to be effective, *see* Pt 5, Ch 19,3.3. The components of the rudder steering gear are to be able to withstand the yield torque of the rudder stock, *see* Pt 5, Ch 19,3.2.2. Rudder stoppers working on the rudder blade or rudder head are to be fitted.

■ *Section 7*
Machinery requirements for first-year ice conditions – Ice Classes 1AS FS, 1A FS, 1B FS and 1C FS

7.1 General

7.1.1 Where the notation **Ice Class 1AS FS**, **Ice Class 1A FS**, **Ice Class 1B FS** or **Ice Class 1C FS** is desired, the requirements of this Section, in addition to those for open water service, are to be complied with, so far as these are applicable.

7.2 Determination of ice torque

7.2.1 Dimensions of propellers, shafting and gearing are determined by formulae taking into account the impact when a propeller blade hits ice. The ensuing load is hereinafter defined by ice torque, *M*.

$M = m\,D^2$ kN m

where

m = 21,10 for **Ice Class 1AS FS**
= 15,69 for **Ice Class 1A FS**
= 13,04 for **Ice Class 1B FS**
= 11,96 for **Ice Class 1C FS**

D = diameter of propeller, in metres

7.2.2 If the propeller is not fully submerged when the ship is in ballast condition, the ice torque for **Ice Class 1A FS** is to be used for **Ice Class 1B FS** and **Ice Class 1C FS**.

7.3 Propeller blade sections

7.3.1 The width, *L*, and thickness, *T*, of propeller blade sections are to be determined so that:

(a) at the radius 0,25*D*/2, for solid propellers

$$LT^2 \geq \frac{26\,478\,000}{\sigma_u\,(0{,}65 + 0{,}7p_r/D)}$$

(b) at radius 0,35*D*/2 for controllable pitch propellers

$$LT^2 \geq \frac{21\,084\,300}{\sigma_u\,(0{,}65 + 0{,}7p_r/D)}$$

(c) at the radius 0,6*D*/2

$$LT^2 \geq \frac{9\,316\,320}{\sigma_u\,(0{,}65 + 0{,}7p_r/D)}$$

where

D = diameter of propeller, in metres
L = length of the expanded cylindrical section of the blade, at the radius in question, in mm
M = ice torque as defined in 7.2
N = number of blades
p_r = propeller pitch at the radius in question, for solid propellers, in metres
= 0,7 nominal pitch for controllable pitch propellers, in metres
P = shaft power as defined in Pt 5, Ch 1,3.3
R = propeller speed, in rev/min
T = the corresponding maximum blade thickness, in mm
σ_u = specified minimum tensile strength of the material, in N/mm^2.

7.3.2 Where the blade thickness derived from these formulae is less than the blade thickness derived by Pt 5, Ch 7,3.1, the latter is to apply.

7.4 Propeller blade minimum tip thickness

7.4.1 The blade tip thickness, *t*, at the radius *D*/2 is to be determined by the following formulae:

Ice Class 1AS FS

$$t = (20 + 2D)\sqrt{\frac{490}{\sigma_u}} \text{ mm}$$

Ice Classes 1A FS, **1B FS** and **1C FS**

$$t = (15 + 2D)\sqrt{\frac{490}{\sigma_u}} \text{ mm}$$

where

D and σ_u = are as defined in 7.3.

7.5 Intermediate blade sections

7.5.1 The thickness of other sections is to conform to a smooth curve connecting the section thicknesses as determined by 7.3 and 7.4.

7.6 Blade edge thickness

7.6.1 The thickness of blade edges is to be not less than 50 per cent of the derived tip thickness, t, measured at 1,25t from edge. For controllable pitch propellers, this applies only to the leading edge.

7.7 Mechanisms for controllable pitch propellers

7.7.1 The strength of mechanisms in the boss of a controllable pitch propeller is to be 1,5 times that of the blade when a load is applied at the radius 0,9D/2 in the weakest direction of the blade.

7.8 Keyless propellers

7.8.1 When it is proposed to use keyless propellers, the fit of the propeller boss to the screwshaft will be specially considered.

7.9 Screwshafts

7.9.1 The diameter d_s at the aft bearing of the screwshaft fitted in conjunction with a solid propeller is to be not less than:

$$d_s = 1{,}08 \sqrt[3]{\frac{\sigma_u L T^2}{\sigma_o}} \text{ mm}$$

where

L and T = proposed width and thickness respectively of the propeller blade section at 0,25D/2, in mm

σ_o = specified minimum yield stress of the material of the screwshaft, in N/mm^2

σ_u = specified minimum tensile strength of the blade material, in N/mm^2

7.9.2 The diameter, d_s at the aft bearing of the screwshaft fitted in conjunction with a controllable pitch propeller is to be not less than:

$$d_s = 1{,}15 \sqrt[3]{\frac{\sigma_u L T^2}{\sigma_o}} \text{ mm}$$

where

L and T = proposed width and thickness respectively of the propeller blade section at 0,35D/2, in mm

σ_o = specified minimum yield stress of the material of the screwshaft, in N/mm^2

σ_u = specified minimum tensile strength of the blade material, in N/mm^2

7.9.3 Where the screwshaft diameter as derived by 7.9.1 or 7.9.2 is less than the diameter derived by Pt 5 Ch 6,3.5.1, the latter is to apply.

7.9.4 The diameter, d_s, of the screwshaft determined in accordance with this Section is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or 2,5d_s whichever is the greater.

7.9.5 The shaft may be tapered at the forward end in accordance with Pt 5, Ch 6,3.5.3 and Pt 5, Ch 6,3.5.4, except for **Ice Class 1AS FS** ice strengthening, where these diameters are to be increased by 10 per cent.

7.10 Intermediate and thrust shafts

7.10.1 The diameters of intermediate shafts and thrust shafts in external bearings are to comply with Pt 5, Ch 6,3.1 and Pt 5, Ch 6,3.4 respectively, except for **Ice Class 1AS FS** ice strengthening where these diameters are to be increased by 10 per cent.

7.11 Reduction gearing

7.11.1 Where gearing is fitted between the engine and the propeller shafting, the gearing is to be in accordance with Pt 5, Ch 5, and is to be designed to transmit a torque, Y_i, taken as the greater of the following conditions:

(a) Ice load conditions (ice torque applied to mean torque)

$$Y_i = Y + \frac{M I_h u^2}{I_l + I_h u^2} \text{ kN m}$$

where

u = gear ratio

$= \dfrac{\textit{pinion speed}}{\textit{wheel speed}}$

I_h = mass moment of inertia of machinery components rotating at higher speed

I_l = mass moment of inertia of machinery components rotating at lower speed, including propeller with an addition of 30 per cent of entrained water (I_h and I_l are to be expressed in the same units)

M = ice torque as defined in 7.2

Y = 9,55 P/R

P and R = are as defined in 7.3

(b) Open water conditions (K_A factor applied to mean torque)

Y_i = $Y K_A$ KN m

Y = as above

K_A = application factor as given in Table 5.3.1 in Pt 5, Ch 5

■ *Section 8*
Hull requirements for first-year ice conditions – Ice classes 1AS FS(+), 1A FS(+), 1B FS(+) and 1C FS(+)

8.1 General

8.1.1 The requirements for **Ice Class 1AS FS**, **Ice Class 1A FS**, **Ice Class 1B FS** and **Ice Class 1C FS**, as applicable, are to be applied using the installed engine power as given by Section 9.

■ Section 9
Machinery requirements for first-year ice conditions - Ice classes 1AS FS(+), 1A FS(+), 1B FS(+) and 1C FS(+)

9.1 Powering of ice strengthened ships

9.1.1 For ships that require additional strengthening in ice, the total shaft power installed is to be calculated using the following Sections, but is not to be less than required by the *Finnish Swedish Ice Class Rules* in force at the time of contract.

9.1.2 Ice strengthened ships which are to be considered to have an icebreaking capability are to be able to develop sufficient thrust to permit continuous mode icebreaking at a speed of at least five knots in ice having a thickness equal to the nominal value for the desired Ice Class and a snow cover of at least 0,3 m.

9.1.3 The shaft power necessary to provide an ice-breaking capability can be determined by the equation:

$$P_1 = 0{,}736 C_1\, C_2\, C_3 \left[240 Bh\,(1 + h + 0{,}035 v^2) + 70 S_c \sqrt{L} \right] \text{ kW}$$

where

B = moulded breath of ship, in metres, *see* Pt 3, Ch 1,6.1.3

L = Rule length, in metres, *see* Pt 3, Ch 1,6.1.1

Δ = displacement, in tonnes, *see* Pt 3, Ch 9,7.2.1

$C_1 = \dfrac{1{,}2B}{\sqrt[3]{\Delta}}$ but is not to be taken as less than 1,0

C_2 = 0,9 if the ship is fitted with a controllable pitch propeller, otherwise 1,0

C_3 = 0,9 if the rake of the stem is 45° or less, otherwise 1,0. The product $C_2\, C_3$ is not to be taken as less than 0,85

C_4 = 1,1 if the ship is fitted with a bulbous bow, otherwise 1,0

h = ice thickness

S_c = depth of snow cover

v = ship speed, in knots, when breaking ice of thickness h.

■ Section 10
Hull strengthening requirements for navigation in multi-year ice conditions – Ice Classes PC1, PC2, PC3, PC4, PC5, PC6 and PC7

10.1 Hull Areas

10.1.1 The hull of all polar class ships is divided into areas reflecting the magnitude of the loads that are expected to act upon them, *see* Fig. 2.10.1. In the longitudinal direction, there are four regions:

(a) bow, (*B*);
(b) bow intermediate, (B_i);
(c) midbody, (*M*), and
(d) stern (*S*).

The bow intermediate, midbody and stern regions are further divided in the vertical direction into three regions:

(i) bottom, (*b*)
(ii) lower, (*l*) and
(iii) icebelt (*i*).

10.1.2 The upper ice waterline, UIWL, and lower ice waterline, LIWL, are as defined in 2.2.

10.1.3 In addition to Fig. 2.10.1, at no time is the boundary between the bow and bow intermediate regions to be forward of the intersection point of the line of the stem and the ship baseline.

10.1.4 In addition to Fig. 2.10.1, the aft boundary of the bow region need not be more than 0,45*L* aft of the forward perpendicular, *FP*.

10.1.5 The boundary between the bottom and lower regions is to be taken at the point where the tangent to the shell is inclined 7° from horizontal.

10.1.6 If a ship is intended to operate astern in ice regions, the aft section of the ship is to be designed based on the bow and bow intermediate hull area requirements.

10.2 Design ice loads – General

10.2.1 For ships of all Polar Classes, a glancing impact on the bow is the design scenario for determining the scantlings required to resist ice loads.

10.2.2 The design ice load is characterized by an average pressure, P_a, uniformly distributed over a rectangular load patch of height, b, and width, w.

10.2.3 Within the bow area of all polar classes, and within the bow intermediate icebelt area of polar classes PC6 and PC7, the ice load parameters are functions of the actual bow shape. To determine the ice load parameters, P_a, b and w, it is required to calculate the following ice load characteristics for sub-regions of the bow area; shape coefficient, f_{ai}, total glancing impact force, F_i, line load, Q_i, and pressure, P_i.

10.2.4 In other ice-strengthened areas, the ice load parameters, P_a, b_{NB} and w_{NB}, are determined independently of the hull shape and based on a fixed load patch aspect ratio, AR = 3.6.

10.2.5 Design ice forces calculated according to 10.3 are only valid for vessels with icebreaking forms. Design ice forces for any other bow forms are to be specially considered.

10.2.6 Ship structures that are not directly subjected to ice loads may still experience inertial loads of stowed cargo and equipment resulting from ship/ice interaction. These inertial loads are to be considered in the design of these structures.

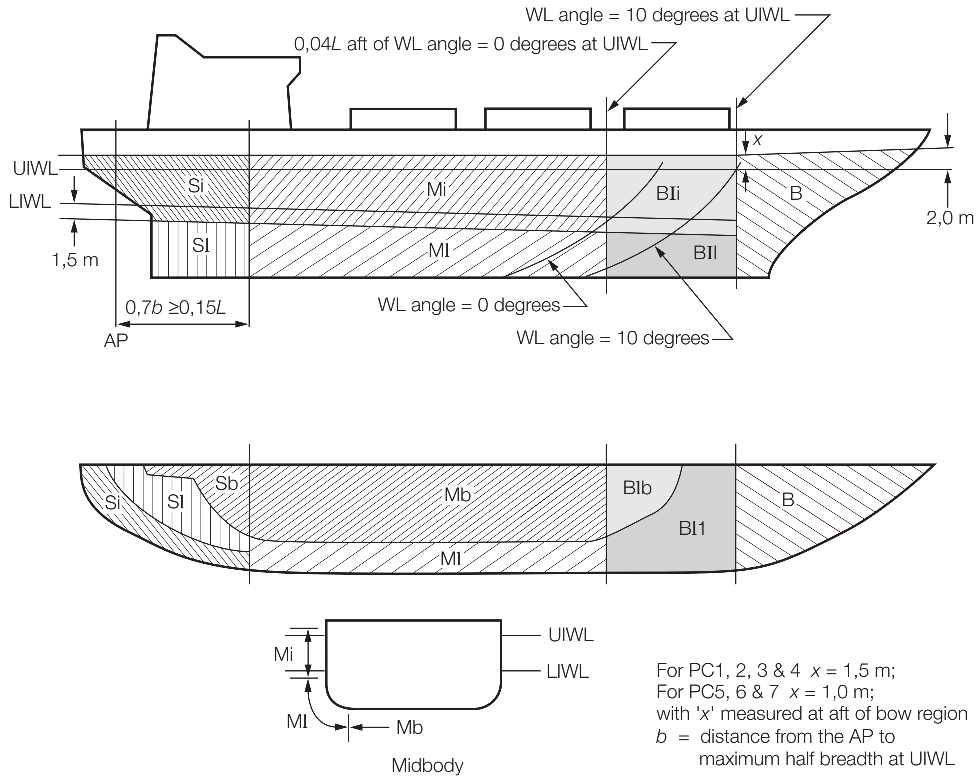


Fig. 2.10.1 Extent of hull areas

10.3 Glancing impact load characteristics

10.3.1 The parameters defining the glancing impact load characteristics are reflected in the class factors listed in Table 2.10.1.

10.4 Bow area

10.4.1 In the bow area, the force, *F*, line load, *Q*, pressure, *P*, and load patch aspect ratio, *AR*, associated with the glancing impact load scenario are functions of the hull angles measured at the upper ice waterline, UIWL. The influence of the hull angles is captured through calculation of a bow shape coefficient, *fa*. The hull angles are defined in Fig. 2.10.2.

10.4.2 The waterline length of the bow region is generally to be divided into four sub-regions of equal length. The force, *F*, line load, *Q*, pressure, *P*, and load patch aspect ratio, *AR*, are to be calculated with respect to the mid - length position of each sub-region (each maximum of *F*, *Q* and *P* is to be used in the calculation of the ice load parameters P_a, *b* and *w*).

10.4.3 The bow area load characteristics are determined as follows:

(a) The shape coefficient, fa_i, is to be taken as

$fa_i = fa_{i,1}$
$fa_{i,2}$
$fa_{i,3}$ whichever is the lesser

where

Table 2.10.1 Class factors

Polar Class	Crushing failure class factor	Flexural failure class factor	Load patch dimensions class factor	Displacement class factor	Longitudinal strength class factor
	C_C	C_F	C_D	C_{DI}	C_L
PC1	17,69	68,60	2,01	250	7,46
PC2	9,89	46,80	1,75	210	5,46
PC3	6,06	21,17	1,53	180	4,17
PC4	4,50	13,48	1,42	130	3,15
PC5	3,10	9,00	1,31	70	2,50
PC6	2,40	5,49	1,17	40	2,37
PC7	1,80	4,06	1,11	22	1,81

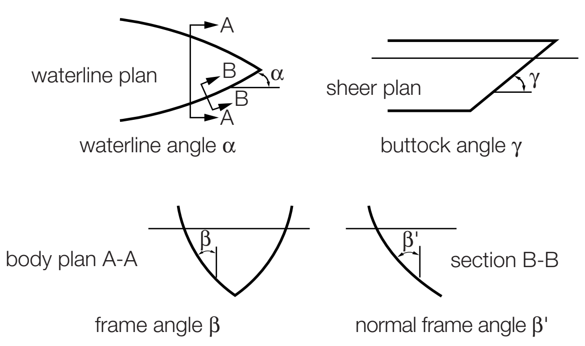


Fig. 2.10.2 Definition of hull angles

$$fa_{i,1} = \left(0{,}097 - 0{,}68\left(\frac{x}{L} - 0{,}15\right)^2\right)\frac{\alpha_i}{\sqrt{\beta'_i}}$$

$$fa_{i,2} = \frac{1{,}2C_F}{\sin(\beta'_i)\, C_C\, \Delta^{0{,}64}}$$

$fa_{i,3}$ = 0,60
i = sub-region considered
L = ship length measured at the upper ice waterline (UIWL), in metres
x = distance from the forward perpendicular (FP) to station under consideration, in metres
α = waterline angle, in degrees, *see* Fig. 2.10.2
β' = normal frame angle, in degrees, *see* Fig. 2.10.2
Δ = ship displacement, in kilo tonnes, not to be taken less than 5
C_C = crushing failure class factor from Table 2.10.1
C_F = flexural failure class factor from Table 2.10.1

(b) Force, F_i:

$$F_i = fa_i\ C_C\ D^{0{,}64} \quad \text{MN}$$

where
i = sub-region considered
fa_i = shape coefficient of sub-region, i
C_C = crushing failure class factor from Table 2.10.1
Δ = ship displacement, in kilo tonnes, not to be taken less than 5

(c) Load patch aspect ratio, AR_i:

AR_i = 7,46 sin (β'_i)
AR_i ≥ 1,3

where
i = sub-region considered
β'_i = normal frame angle of sub-region i, in degrees

(d) Line load, Q_i:

$$Q_i = \frac{F_i^{0{,}61}\ C_D}{AR_i^{0{,}35}} \quad \text{MN/m}$$

where
i = sub-region considered
F_i = force of sub-region i, in MN
C_D = load patch dimensions class factor from Table 2.10.1
AR_i = load patch aspect ratio of sub-region i

(e) Pressure, P_i:

$$P_i = F_i^{0{,}22}\ C_D^2\ AR_i^{0{,}3} \quad \text{MPa}$$

where
I = sub-region considered
F_i = force of sub-region i, in MN
C_D = load patch dimensions class factor from Table 2.10.1
AR_i = load patch aspect ratio of sub-region i

10.5 Hull areas other than the bow

10.5.1 In the hull areas other than the bow, the force, F_{NB}, and line load, Q_{NB}, used in the determination of the load patch dimensions, b_{NB}, w_{NB}, and design pressure, P_a, are determined as follows:

(a) Force, F_{NB}:

$$F_{NB} = 0{,}36C_C\ \Delta_F \quad \text{MN}$$

where
C_C = crushing force class factor from Table 2.10.1
Δ_F = ship displacement factor
= $\Delta^{0{,}64}$ if $\Delta \le C_{DI}$
= $CF_{DIS}^{0{,}64} + 0{,}10\,(\Delta - C_{DI})$ if $\Delta > C_{DI}$
Δ = ship displacement, in kilo tonnes, not to be taken less than 10
C_{DI} = displacement class factor from Table 2.10.1

(b) Line Load, Q_{NB}:

$$Q_{NB} = 0{,}639F_{NB}^{0{,}61}\ C_D \quad \text{MN/m}$$

where
F_{NB} = force from 10.5.1(a), in MN
C_D = load patch dimensions class factor from Table 2.10.1

10.6 Design load patch

10.6.1 In the bow area, and the bow Intermediate Icebelt area for ships with class notation PC6 and PC7, the design load patch has dimensions of width, w_B, and height, b_B, defined as follows:

$$w_B = \frac{F_B}{Q_B} \quad \text{m}$$

$$b_B = \frac{Q_B}{P_B} \quad \text{m}$$

where
F_B = maximum F_i in the bow area, in MN
Q_B = maximum Q_i in the bow area, in MN/m
P_B = maximum P_i in the bow area, in MPa

10.6.2 In hull areas other than those covered by 10.6.1, the design load patch has dimensions of width, w_{NB}, and height, b_{NB}, defined as follows:

$$w_{NB} = \frac{F_{NB}}{Q_{NB}} \quad \text{m}$$

$$b_{NB} = \frac{w_{NB}}{3{,}6} \quad \text{m}$$

where
F_{NB} = force determined using 10.5.1(a), in MN
Q_{NB} = line load determined using 10.5.1(b), in MN/m.

10.7 Pressure within the design load patch

10.7.1 The average pressure, P_a, within a design load patch is determined as follows:

$$P_a = \frac{F}{bw} \text{ MPa}$$

where

F = F_B or F_{NB} as appropriate for the hull area under consideration, in MN

b = b_B or b_{NB} as appropriate for the hull area under consideration, in metres

w = w_B or w_{NB} as appropriate for the hull area under consideration, in metres.

10.7.2 Areas of higher, concentrated pressure exist within the load patch. In general, smaller areas have higher local pressures. Accordingly, the peak pressure factors listed in Table 2.10.2 are used to account for the pressure concentration on localized structural members.

10.8 Hull area factors

10.8.1 Associated with each hull area is an area factor that reflects the relative magnitude of the load expected in that area. The area factor, *AF*, for each hull area is listed in Table 2.10.3.

10.8.2 In the event that a structural member spans across the boundary of a hull area, the largest hull area factor is to be used in the scantling determination of the member.

10.8.3 Due to their increased manoeuvrability, ships having propulsion arrangements with azimuthing thruster(s) or podded propellers shall have specially considered stern icebelt, S_i, and stern lower, S_l, hull area factors.

10.9 Shell plate requirements

10.9.1 The required minimum shell plate thickness, t, is given by:

$$t = t_{net} + t_s \text{ mm}$$

where

t_{net} = plate thickness required to resist ice loads according to 10.9.2, in mm

t_s = corrosion and abrasion allowance according to 10.16, in mm.

10.9.2 The thickness of shell plating required to resist the design ice load, t_{net}, depends on the orientation of the framing. The plating, including all bottom plating, i.e. plating in hull areas B_{lb}, M_b and S_b, the net thickness is given by Table 2.10.4.

10.10 Framing – General

10.10.1 Framing members of Polar class ships are to be designed to withstand the ice loads defined in 10.2.

10.10.2 The term ‘framing member’ refers to transverse and longitudinal local frames, load-carrying stringers and web frames in the areas of the hull exposed to ice pressure, *see* Fig. 2.10.1. Where load-distributing stringers have been fitted, the arrangement and scantlings of these are to be suitably designed.

10.10.3 The strength of a framing member is dependent upon the fixity that is provided at its supports. Fixity can be assumed where framing members are either continuous through the support or attached to a supporting section with a connection bracket. In other cases, simple support is to be assumed unless the connection can be demonstrated to provide significant rotational restraint. Fixity is to be ensured at the support of any framing which terminates within an ice-strengthened area.

10.10.4 The details of framing member intersection with other framing members, including plated structures, as well as the details for securing the ends of framing members at supporting sections, are to be in accordance with Pt 3, Ch 10.

Table 2.10.2 Peak pressure factors

Structural member		Peak pressure factor, K_i
Plating	Transversely framed Longitudinally framed	$K_p = (1{,}8 - s) \geq 1{,}2$ $K_p = (2{,}2 - 1{,}2s) \geq 1{,}5$
Frames in transverse framing systems	With load distributing stringers With no load distributing stringers	$K_t = (1{,}6 - s) \geq 1{,}0$ $K_t = (1{,}8 - s) \geq 1{,}2$
Load carrying stringers Side and bottom longitudinals Web frames		$K_s = 1$ if $S_w \geq 0{,}5w$ $K_s = 2 - \frac{2S_w}{w}$ if $S_w < 0{,}5w$
Symbols		
s = frame or longitudinal spacing, in metres S_w = web frame spacing, in metres w = ice load patch width, in metres		

Table 2.10.3 Hull area factors (*AF*)

Hull area		Area	Polar class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (*B*)	All	B	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Bow intermediate (*BI*)	Icebelt	BI_i	0,90	0,85	0,85	0,80	0,80	1,00 *see* Note 1	1,00 *see* Note 1
	Lower	BI_l	0,70	0,65	0,65	0,60	0,55	0,55	0,50
	Bottom	BI_b	0,55	0,50	0,45	0,40	0,35	0,30	0,25
Midbody (*M*)	Icebelt	M_i	0,70	0,65	0,55	0,55	0,50	0,45	0,45
	Lower	M_l	0,50	0,45	0,40	0,35	0,30	0,25	0,25
	Bottom	M_b	0,30	0,30	0,25	*see* Note 2	*see* Note 2	*see* Note 2	*see* Note 2
Stern (*S*)	Icebelt	S_i	0,75	0,70	0,65	0,60	0,50	0,40	0,35
	Lower	S_l	0,45	0,40	0,35	0,30	0,25	0,25	0,25
	Bottom	S_b	0,35	0,30	0,30	0,25	0,15	*see* Note 2	*see* Note 2

NOTES
1. *See* 10.2.3.
2. Indicates that strengthening for ice loads is not necessary.

Table 2.10.4 Shell plate thickness

Transversely framed plating	Obliquely framed plating	Longitudinally framed plating	
		$\Omega \leq 20°$	
$\Omega \geq 70°$	$70° > \Omega > 20°$	$b \geq s$	$b < s$
$t_{net} = \dfrac{500s\sqrt{\dfrac{AF\,K_p\,P_a}{\sigma_y}}}{1+\dfrac{s}{2b}}$ mm	linear interpolation	$t_{net} = \dfrac{500s\sqrt{\dfrac{AF\,K_p\,P_a}{\sigma_y}}}{1+\dfrac{s}{2l}}$ mm	$t_{net} = \dfrac{500s\sqrt{\dfrac{AF\,K_p\,P_a}{\sigma_y}}\sqrt{\dfrac{2b}{s}-\left(\dfrac{b}{s}\right)^2}}{1+\dfrac{s}{2l}}$ mm

Symbols

Ω = smallest angle between the chord of the waterline and the line of the first level framing as illustrated in Fig. 2.10.3, in degrees
s = transverse frame spacing in transversely-framed ships or longitudinal frame spacing in longitudinally-framed ships, in metres
AF = hull area factor from Table 2.10.3
K_p = peak pressure factor from Table 2.10.2
P_a = average patch pressure according to 10.7.1, in MPa
σ_y = minimum upper yield stress of the material, in N/mm^2
b = height of design load patch, in m, where $b \leq l - \dfrac{s}{4}$ in the case of transversely framed plating
l = distance between frame supports, i.e. equal to the frame span as given in 10.10.5, but not reduced for any fitted end brackets, in metres. When a load-distributing stringer is fitted, the length, l, need not be taken larger than the distance from the stringer to the most distant frame support

10.10.5 The design span of a framing member is to be determined on the basis of its moulded length. If brackets are fitted, the design span may be reduced in accordance with Pt 3, Ch 3.

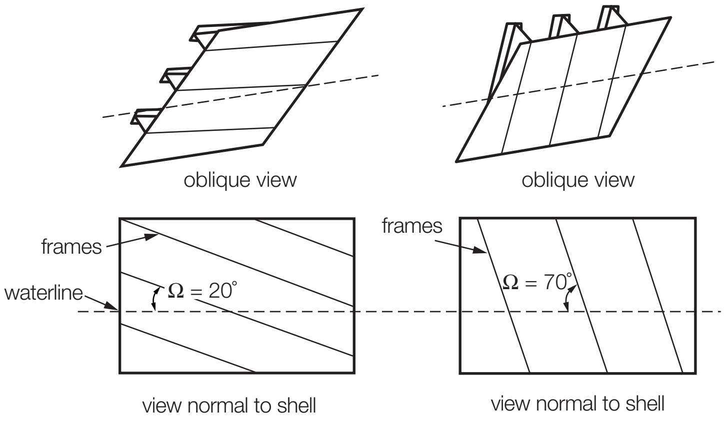


Fig. 2.10.3 Shell framing angle Ω

10.10.6 When calculating the section modulus and shear area of a framing member, the net thicknesses of the web, flange (if fitted) and attached shell plating are to be used. The shear area of a framing member may include that material contained over the full depth of the member, i.e. web area including portion of flange, if fitted, but excluding attached shell plating.

10.10.7 The actual net effective shear area, A_w, of a framing member is given by:

$$A_w = h\, t_{wn} \sin\left(\frac{\varphi_w}{100}\right) \text{ cm}^3$$

where

h = height of stiffener, in mm, *see* Fig. 2.10.4
t_{wn} = net web thickness, in mm
= $t_w - t_c$
t_w = as built web thickness, in mm, *see* Fig. 2.10.4
t_c = corrosion deduction, in mm, to be subtracted from the web and flange thickness (as specified in Table 2.10.5, but not less than ts as required by 10.16.3)
φ_w = smallest angle between shell plate and stiffener web, measured at the midspan of the stiffener, *see* Fig. 2.10.4. The angle φ_w may be taken as 90° provided the smallest angle is not less than 75°.

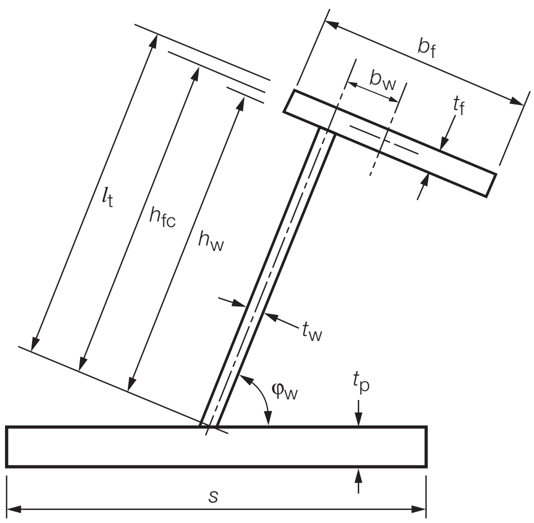


Fig. 2.10.4 Stiffener geometry

Table 2.10.5 Corrosion deductions for web and flange thickness

Category		Corrosion deduction t_c, in mm
Ballast water tanks	Within 3 m below the top of tank, *see* Note	4,0
	Elsewhere	3,0
Cargo oil tanks	Within 3 m below the top of tank, *see* Note	4,0
	Elsewhere	2,5
Heated cargo oil tanks	Within 3 m below the top of tank, *see* Note	4,5
	Elsewhere	3,5
Void spaces	Spaces not normally accessed, e.g. access only via bolted manhole openings, pipe tunnels, etc.	2,0
Dry spaces	Internals of machinery spaces, pump room, store rooms, steering gear space, etc.	1,5
NOTE Only applicable to cargo and ballast tanks with weather deck as the tank top.		

10.10.8 When the cross-sectional area of the attached plate flange exceeds the cross-sectional area of the local frame, the actual net effective plastic section modulus, Z_p, is given by:

$$Z_p = \frac{A_{pn}\, t_{pn}}{20} + \frac{h_w^2\, t_{wn} \sin\varphi_w}{2000} + \frac{A_{fn}\,(h_{fc} \sin\varphi_w - b_w \cos\varphi_w)}{10} \text{ cm}^3$$

where

A_{pn} = net cross-sectional area of attached plate, in cm^2 (equal to 10s t_{pn}, but not to be taken greater than the net cross-sectional area of the local frame)

t_{pn} = fitted net shell plate thickness, in mm, (shall comply with t_{net} as required by 10.9.2)

h_w = height of local frame web, in mm, *see* Fig. 2.10.4

A_{fn} = net cross-sectional area of local frame flange, in cm^2

h_{fc} = height of local frame measured to centre of the flange area, in mm, *see* Fig. 2.10.4

b_w = distance from mid thickness plane of local frame web to the centre of the flange area, in mm, *see* Fig. 2.10.4

h, t_w, t_c and φ_w are as given in 10.10.7

s as given in 10.9.2.

10.10.9 When the cross-sectional area of the local frame exceeds the cross-sectional area of the attached plate flange, the plastic neutral axis is located a distance z_{na} above the attached shell plate, given by:

$$z_{na} = \frac{100\, A_{fn} + h_w\, t_{wn} - 1000 t_{pn}\, s}{2 t_{wn}} \text{ mm}$$

and the net effective plastic section modulus, Z_p, is given by:

$$Z_p = t_{pn}\, s\, z_{na} \sin\varphi_w + \left(\frac{(h_w - z_{na})^2 + z_{na}^2)\, t_{wn} \sin\varphi_w}{2000} + \frac{A_{fn}\,((h_{fc} - z_{na}) \sin\varphi_w - b_w \cos\varphi_w)}{10} \right) \text{ cm}^3$$

10.10.10 In the case of oblique framing arrangement (70° > Ω > 20°, where Ω is defined as given in 10.9.2), linear interpolation is to be used.

10.11 Framing – Transversely-framed side structures and bottom structures

10.11.1 The local frames in transversely-framed side structures and in bottom structures (i.e. hull areas B_{Ib}, M_b and S_b) are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism.

10.11.2 The actual net effective shear area of the frame, A_w, as defined in 10.10.7, is to comply with the following condition:

$$A_w \geq A_t$$

where

$$A_t = 5000\, l_L\, s\, \frac{AF\, K_t\, P_a}{0{,}577 \sigma_y} \text{ cm}^2$$

l_L = length of loaded portion of span, in metres
= need not exceed the lesser of a and b

a = frame span as defined in 10.10.5, in metres

b = height of design ice load patch according to 10.6, in metres

s = transverse frame spacing, in metres

AF = hull area factor from Table 2.10.3

K_t = peak pressure factor from Table 2.10.2

P_a = average pressure within load patch according to 2.10.7, in MPa

σ_y = minimum upper yield stress of the material, in N/mm^2

10.11.3 The actual net effective plastic section modulus of the plate/stiffener combination, Z_p, as defined in 10.10.8 or 10.10.9, is to comply with the following conditions and is to be the greatest of the two load conditions:

(a) ice load acting at the midspan of the transverse frame, and

(b) the ice load acting near a support.

$$Z_p \geq Z_{pt}$$

where

$$Z_{pt} = \frac{100^3\, l_L\, Y\, s\, AF\, K_t\, P_a\, a\, A_1}{4 \sigma_y} \text{ cm}^3$$

$$Y = 1 - \frac{l_L}{2a}$$

A_1 = reflects the two conditions and is to be taken as the greater of A_{1A} or A_{1B}

$$A_{1A} = \frac{1}{1 + \frac{j}{2} + k_w \frac{j}{2} \left(\sqrt{1 - a_1^2} - 1 \right)}$$

$$A_{1B} = \frac{1 - \frac{1}{2 a_1\, Y}}{0{,}275 + 1{,}44 k_z^{0{,}7}}$$

j = 1 for framing with one simple support outside the ice strengthened areas
= 2 for framing without any simple supports

$$a_1 = \frac{A_t}{A_w}$$

A_t = rule minimum shear area of transverse frame as given in 10.11.2, in cm^2

A_w = effective net shear area of transverse frame (calculated according to 10.10.7), in cm^2

$$k_w = \frac{1}{1 + \frac{2 A_{fn}}{A_w}}$$

A_{fn} = as given in 10.10.8

k_z = $\frac{z_p}{Z_p}$ in general

= 0 when the frame is arranged with end bracket

z_p = sum of individual plastic section modulii of flange and shell plate as fitted, in cm^3

$$= \frac{\frac{b_f\, t_{fn}^2}{4} + \frac{b_e\, t_{pn}^2}{4}}{1000}$$

b_f = flange breadth, in mm, *see* Fig. 2.10.4

t_{fn} = net flange thickness, in mm

= $t_f - t_c$

t_c = as given in 10.10.7

t_f = as-built flange thickness, in mm, *see* Fig. 2.10.4

t_{pn} = the fitted net shell plate thickness, in mm, but is not to be less than t_n as given in 10.9

b_e = effective width of shell plate flange, in mm

= $500s$

Z_p = net effective plastic section modulus of transverse frame (calculated according to 10.10.8 or 10.10.9), in cm^3

AF, K_t, P_a, l_L, b, s, a and σ_y are as given in 10.11.2.

10.11.4 The scantlings of the frame are to meet the structural stability requirements of 10.14.

10.12 Framing – Side longitudinals (longitudinally framed ships)

10.12.1 Side longitudinals are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism.

10.12.2 The actual net effective shear area of the frame, A_w, as defined in 10.10.7, is to comply with the following condition:

$$A_w \geq A_L$$

where

$$A_L = \frac{5000\, AF\, K_s\, P_a\, b_1\, a}{0{,}577\sigma_y} \text{ cm}^2$$

AF = hull area factor from Table 2.10.3

K_s = peak pressure factor from Table 2.10.2

P_a = average pressure within load patch according to 10.7.1, in MPa

B_1 = $k_o\, b_2$ m

k_o = $1 - \frac{0{,}3}{b'}$

b' = $\frac{b}{s}$

b = height of design ice load patch from 10.6, in metres

s = spacing of longitudinal frames, in metres

b_2 = $b\,(1 - 0{,}25b')$ m if $b' < 2$

= s m if $b' \geq 2$

a = longitudinal design span as given in 10.10.5, in metres

σ_y = minimum upper yield stress of the material, in N/mm^2

10.12.3 The actual net effective plastic section modulus of the plate/stiffener combination, Z_p, as defined in 10.10.8 or 10.10.9, is to comply with the following condition:

$$Z_p \geq Z_{pL}$$

where

$$Z_{pL} = \frac{100^3\, AF\, K_s\, P_a\, b_1\, a^2\, A_4}{8\sigma_y} \text{ cm}^3$$

$$A_4 = \frac{1}{2 + k_{wl}\left(\sqrt{1 - a_4^2} - 1\right)}$$

$$a_4 = \frac{A_L}{A_w}$$

A_L = rule minimum shear area for longitudinal as given in 10.12.2, in cm^2

A_w = net effective shear area of longitudinal (calculated according to 10.10.7), in cm^2

$$k_{wl} = \frac{1}{1 + \frac{2A_{fn}}{A_w}}$$

A_{fn} = as given in 10.10.8

AF, K_s, P_a, b_1, a and σ_y are as given in 10.12.2.

10.12.4 The scantlings of the longitudinals are to meet the structural stability requirements of 10.14.

10.13 Framing – Web frame and load carrying stringers

10.13.1 Web frames and load-carrying stringers are to be designed to withstand the ice load patch as defined in 10.7. The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimised.

10.13.2 Web frames and load-carrying stringers are to be dimensioned to take into account the combined effects of shear and bending. Where these members form part of a structural grillage system, appropriate methods of analysis are to be used. Where the structural configuration is such that members do not form part of a grillage system, the appropriate peak pressure factor, K_i, from Table 2.10.2 is to be used. Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.

10.13.3 The scantlings of web frames and load-carrying stringers are to meet the structural stability requirements of 10.14.

10.14 Framing – Structural stability

10.14.1 To prevent local buckling in the web, the ratio of web height, h_w, to net web thickness, t_{wn}, of any framing member is not to exceed:

For flat bar sections: $\frac{h_w}{t_{wn}} \leq \frac{282}{\sqrt{\sigma_y}}$

For bulb, tee and angle sections: $\frac{h_w}{t_{wn}} \leq \frac{805}{\sqrt{\sigma_y}}$

where

h_w = web height
t_{wn} = net web thickness
σ_y = minimum upper yield stress of the material, in N/mm^2

10.14.2 Framing members for which it is not practicable to meet the requirements of 10.14.1 (e.g. load carrying stringers or deep web frames) are required to have their webs effectively stiffened. The scantlings of the web stiffeners are to ensure the structural stability of the framing member. The minimum net web thickness for these framing members is given by:

$$t_{wn} = 2{,}63 \times 10^{-3}\, c_1 \frac{\sigma_y}{5{,}34 + 4\left(\frac{c_1}{c_2}\right)^2} \text{ mm}$$

where
c_1 = $h_w - 0{,}8h$ mm
h_w = web height of stringer/web frame, in mm, *see* Fig. 2.10.5
h = height of framing member penetrating the member under consideration (to be taken as zero if no such framing member is fitted), in mm, *see* Fig. 2.10.5
c_2 = spacing between supporting structure oriented perpendicular to the member under consideration, in mm, *see* Fig. 2.10.5
σ_y = minimum upper yield stress of the material, in N/mm^2

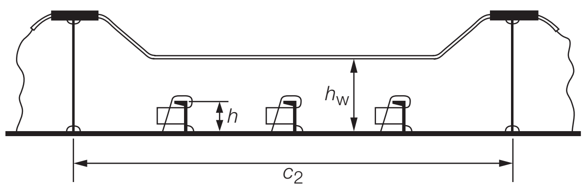


Fig. 2.10.5 Parameter definition for web stiffening

10.14.3 In addition, the following is to be satisfied:

$$t_{wn} \geq 0{,}35 t_{pn} \sqrt{\frac{\sigma_y}{235}}$$

where
σ_y = minimum upper yield stress of the material, in N/mm^2
t_{wn} = net thickness of the web, in mm
t_{pn} = net thickness of the shell plate in way the framing member, in mm.

10.14.4 To prevent local flange buckling of welded profiles, the following are to be satisfied:
(a) The flange width, b_f, in mm, is not to be less than five times the net thickness of the web, t_{wn}.
(b) The flange outstand, b_o, in mm, is to meet the following requirement:

$$\frac{b_o}{t_{fn}} \leq \frac{155}{\sqrt{\sigma_y}}$$

where
t_{fn} = net thickness of flange, in mm
σ_y = minimum upper yield stress of the material, in N/mm^2.

10.15 Plated structures

10.15.1 Plated structures are those stiffened plate elements in contact with the hull and subject to ice loads. These requirements are applicable to an inboard extent which is the lesser of:
(a) web height of adjacent parallel web frame or stringer; or
(b) 2,5 times the depth of framing that intersects the plated structure.

10.15.2 The thickness of the plating and the scantlings of attached stiffeners are to be such that the degree of end fixity necessary for the shell framing is ensured.

10.15.3 The stability of the plated structure is to adequately withstand the ice loads defined in 10.7.

10.16 Corrosion/abrasion additions and steel renewal

10.16.1 Effective protection against corrosion and ice-induced abrasion is recommended for all external surfaces of the shell plating for all Polar ships.

10.16.2 The values of corrosion/abrasion additions, t_s, to be used in determining the shell plate thickness for each Polar Class are listed in Table 2.10.6.

10.16.3 Polar ships are to have a minimum corrosion/abrasion addition of t_s = 1,0 mm applied to all internal structures within the ice strengthened hull areas, including plated members adjacent to the shell, as well as stiffener webs and flanges.

10.16.4 Steel renewal for ice strengthened structures is required when the gauged thickness is less than t_n + 0,5 mm.

10.17 Materials

10.17.1 Plating materials for hull structures are to be not less than those given in Tables 2.10.8 to 2.10.11 based on the as-built thickness of the material, the Polar ice class notation assigned to the ship and the material class of structural members given in Table 2.10.7.

10.17.2 Material classes specified in Table 2.2.1 in Pt 3, Ch 2, are applicable to polar ships regardless of the ship's length. In addition, material classes for weather and sea exposed structural members and for members attached to the weather and sea exposed shell plating of polar ships are given in Table 2.10.7. Where the material classes in Table 2.10.7 and those in Table 2.2.1 in Pt 3, Ch 2 differ, the higher material class is to be applied.

Table 2.10.6 Corrosion/abrasion additions for shell plating

Hull area	t_s, in mm					
	With effective protection			Without effective protection		
	PC1 – PC3	PC4 and PC5	PC6 and PC7	PC1 – PC3	PC4 and PC5	PC6 and PC7
Bow; Bow Intermediate Icebelt	3,5	2,5	2,0	7,0	5,0	4,0
Bow Intermediate Lower; Midbody & Stern Icebelt	2,5	2,0	2,0	5,0	4,0	3,0
Midbody and Stern Lower; Bottom	2,0	2,0	2,0	4,0	3,0	2,5
Other Areas	2,0	2,0	2,0	3,5	2,5	2,0

Table 2.10.7 Material classes for structural members of polar ships

Structural members	Material Class
Shell plating within the bow and bow intermediate icebelt hull areas (B, B_{Ii})	II
Plating materials for stem and stern frames, rudder horn, rudder, propeller nozzle, shaft brackets, ice skeg, ice knife and other appendages subject to ice impact loads	II
All weather and sea exposed SPECIAL, as defined in Table 2.2.1 in Pt 3, Ch 2, structural members within 0,2*L* from FP	II
All weather and sea exposed SECONDARY and PRIMARY, as defined in Table 2.2.1 in Pt 3, Ch 2, structural members outside 0,4*L* amidships	I
All inboard framing members attached to the weather and sea-exposed plating including any contiguous inboard member within 600 mm of the shell plating	I
Weather-exposed plating and attached framing in cargo holds of ships which by nature of their trade have their cargo hold hatches open during cold weather operations	I

10.17.3 Steel grades for all plating and attached framing of hull structures and appendages situated below the level of 0,3 m below the lower waterline, as shown in Fig. 2.10.6, are to be obtained from Table 2.2.2 in Pt 3, Ch 2, based on the material class for Structural Members in Table 2.10.7 above, regardless of Polar Class.

10.17.4 Steel grades for all weather exposed plating of hull structures and appendages situated above the level of 0,3 m below the lower ice waterline, as shown in Fig. 2.10.6, are to be not less than given in Table 2.10.8 to Table 2.10.10.

10.17.5 Steel grades for all inboard framing members attached to weather exposed plating are to be not less than given in Table 2.10.11. This applies to all inboard framing members as well as to other contiguous inboard members (e.g. bulkheads, decks) within 600 mm of the exposed plating.

10.17.6 Castings are to have specified properties consistent with the expected service temperature for the cast component.

10.18 Longitudinal strength – Application

10.18.1 Ice loads need only be combined with still water loads. The combined stresses are to be compared against permissible bending and shear stresses at different locations along the ship's length. In addition, sufficient local buckling strength is also to be verified.

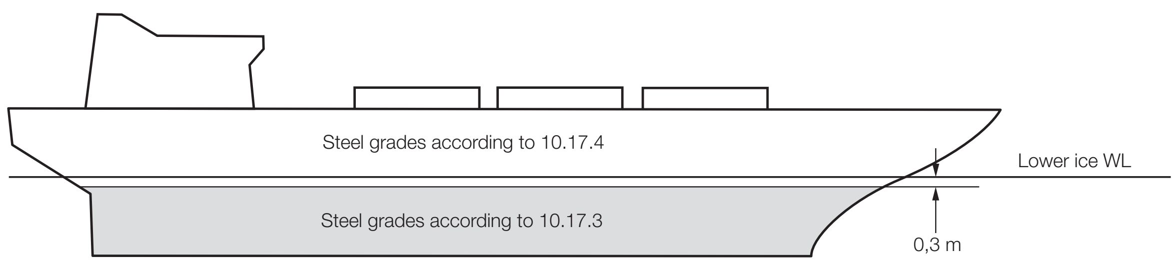


Fig. 2.10.6 Steel grade requirements for submerged and weather exposed shell plating

Table 2.10.8 Steel grades for weather exposed plating

Thickness, t mm	Material Class I			
	PC1 – 5		PC6 and 7	
	MS	HT	MS	HT
$t \leq 10$	B	AH	B	AH
$10 < t \leq 15$	B	AH	B	AH
$15 < t \leq 20$	D	DH	B	AH
$20 < t \leq 25$	D	DH	B	AH
$25 < t \leq 30$	D	DH	B	AH
$30 < t \leq 35$	D	DH	B	AH
$35 < t \leq 40$	D	DH	D	DH
$40 < t \leq 45$	E	EH	D	DH
$45 < t \leq 50$	E	EH	D	DH

NOTE
Includes weather exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0,3 m below the lowest ice waterline.

Table 2.10.9 Steel grades for weather exposed plating

Thickness, t mm	Material Class II			
	PC1 – 5		PC6 and 7	
	MS	HT	MS	HT
$t \leq 10$	B	AH	B	AH
$10 < t \leq 15$	D	DH	B	AH
$15 < t \leq 20$	D	DH	B	AH
$20 < t \leq 25$	D	DH	B	AH
$25 < t \leq 30$	E	EH, *see* Note 2	D	DH
$30 < t \leq 35$	E	EH	D	DH
$35 < t \leq 40$	E	EH	D	DH
$40 < t \leq 45$	E	EH	D	DH
$45 < t \leq 50$	E	EH	D	DH

NOTES
1. Includes weather exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0,3 m below the lowest ice waterline.
2. Grades D, DH are allowed for a single strake of side shell plating not more than 1,8 m wide from 0,3 m below the lowest ice waterline.

Table 2.10.10 Steel grades for weather exposed plating

Thickness, t mm	Material Class III					
	PC1 – 3		PC4 and 5		PC6 and 7	
	MS	HT	MS	HT	MS	HT
$t \leq 10$	E	EH	E	EH	B	AH
$10 < t \leq 15$	E	EH	E	EH	D	DH
$15 < t \leq 20$	E	EH	E	EH	D	DH
$20 < t \leq 25$	E	EH	E	EH	D	DH
$25 < t \leq 30$	E	EH	E	EH	E	EH
$30 < t \leq 35$	E	EH	E	EH	E	EH
$35 < t \leq 40$	F	FH	E	EH	E	EH
$40 < t \leq 45$	F	FH	E	EH	E	EH
$45 < t \leq 50$	F	FH	F	FH	E	EH

NOTE
Includes weather exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0,3 m below the lowest ice waterline.

Table 2.10.11 Steel grades for inboard framing members attached to weather exposed plating

Thickness, t mm	PC1 – PC5		PC6 and 7	
	MS	HT	MS	HT
$t \leq 20$	B	AH	B	AH
$20 < t \leq 35$	D	DH	B	AH
$35 < t \leq 45$	D	DH	D	DH
$45 < t \leq 50$	E	EH	D	DH

10.19 Design vertical ice force at the bow

10.19.1 The design vertical ice force at the bow, F_{IB}, is to be taken as the lesser of $F_{IB,1}$ or $F_{IB,2}$:

$F_{IB,1} = 0{,}534 C_L K_I^{0,15} \sin^{0,2}(\gamma_s) \sqrt{DK_h}$ MN

$F_{IB,2} = 1{,}2 C_F$ MN

where

K_I = indentation parameter

$$= \frac{K_f}{K_h}$$

K_f = for blunt bow forms:

$$K_f = \left(\frac{2C\,B^{(1-e_b)}}{1+e_b}\right)^{0,9} \tan(\gamma_s)^{-0,9(1+e_b)}$$

= for wedge bow forms ($\alpha < 80$ deg), $e_b = 1$ and the above simplifies to:

$$K_f = \left(\frac{\tan(\alpha)}{\tan^2(\gamma_s)}\right)^{0,9}$$

K_h = $0{,}01 A_{wp}$ MN/m

C_L = longitudinal strength class factor from Table 2.10.1

e_b = bow shape exponent which best describes the waterplane (*see* Figs. 2.10.7 and 2.10.8).
An approximate e_b determined by a simple fit is acceptable

= 1,0 for a simple wedge bow form

= 0,4 to 0,6 for a spoon bow form

= 0 for a landing craft bow form

γ_s = stem angle to be measured between the horizontal axis and the stem tangent at the upper ice waterline, in degrees (buttock angle as per Fig. 2.10.2 measured on the centreline)

$$C = \frac{1}{2\left(\frac{L_B}{B}\right)^{eb}}$$

B = ship moulded breadth, in metres

L_B = bow length, in m, used in the equation:

$$y = \frac{B}{2\left(\frac{x}{L_B}\right)^{eb}}$$ (*see* Figs. 2.10.7 and 2.10.8)

Δ = ship displacement, in kilo tonnes, not to be taken less than 10

A_{wp} = ship waterplane area, in m^2

C_F = flexural failure class factor from Table 2.10.1

Where applicable, draught dependent quantities are to be determined at the waterline corresponding to the loading condition under consideration.

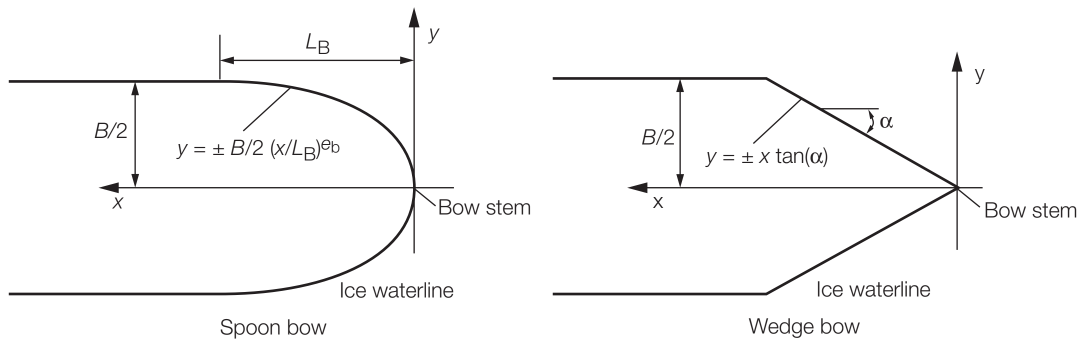


Fig. 2.10.7 Bow shape definition

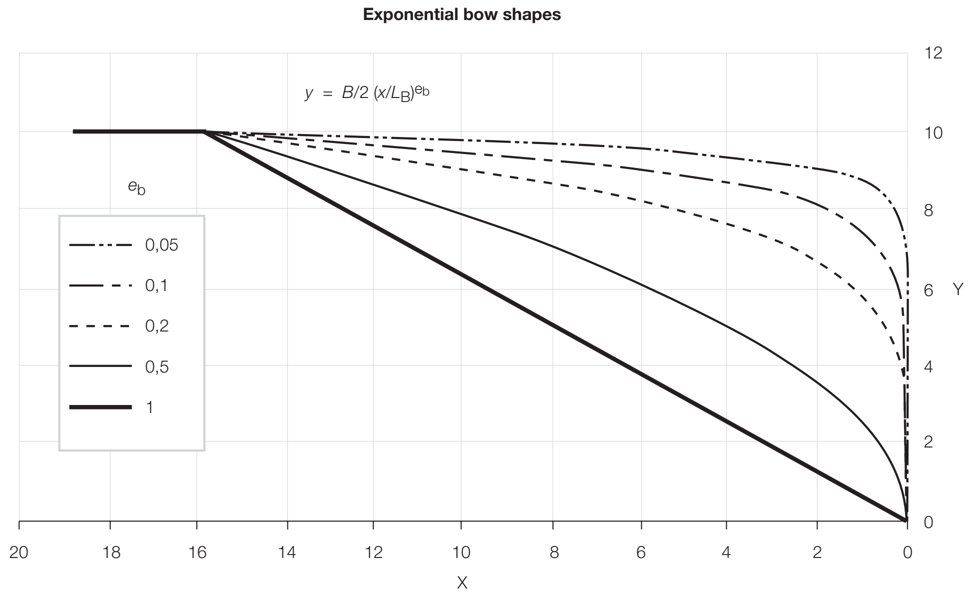


Fig. 2.10.8 Illustration of effect on the bow shape e_b, for B = 20 and L_B = 16

10.20 Design vertical shear force

10.20.1 The design vertical ice shear force, F_I, along the hull girder is to be taken as:

$F_I = C_f F_{IB}$ MN

where

C_f = longitudinal distribution factor to be taken as follows:

(a) Positive shear force

C_f = 0,0 between the aft end of L and 0,6L from aft

C_f = 1,0 between 0,9L from aft and the forward end of L

(b) Negative shear force

C_f = 0,0 at the aft end of L

C_f = -0,5 between 0,2L and 0,6L from aft

C_f = 0,0 between 0,8L from aft and the forward end of L

Intermediate values are to be determined by linear interpolation.

10.20.2 The applied vertical shear stress, τ_a, is to be determined along the hull girder in a similar manner as in Pt 3, Ch 4 by substituting the design vertical ice shear force for the design vertical wave shear force.

10.21 Design vertical ice bending moment

10.21.1 The design vertical ice bending moment, M_I, along the hull girder is to be taken as:

$M_I = 0,1\ C_m\ L \sin^{-0,2}(\gamma_s)\ F_{IB}$ MNm

where

L = ship length (as defined in Pt 3, Ch 1,6.1.1), in metres

γ_{stem} = as given in 10.19.1

F_{IB} = design vertical ice force at the bow, in MN

C_m = longitudinal distribution factor for design vertical ice bending moment to be taken as follows:

C_m = 0,0 at the aft end of L

C_m = 1,0 between 0,5L and 0,7L from aft

C_m = 0,3 at 0,95L from aft

C_m = 0,0 at the forward end of L

Intermediate values are to be determined by linear interpolation.
Where applicable, draught dependent quantities are to be determined at the waterline corresponding to the loading condition under consideration.

10.21.2 The applied vertical bending stress, σ_a, is to be determined along the hull girder in a similar manner as in Pt 3, Ch 4, by substituting the design vertical ice bending moment for the design vertical wave bending moment. The ship still water bending moment is to be taken as the maximum sagging moment.

10.22 Longitudinal strength criteria

10.22.1 The strength criteria provided in Table 2.10.12 are to be satisfied. The design stress is not to exceed the permissible stress.

Table 2.10.12 Longitudinal strength criteria

Failure mode	Applied stress	Permissible stress $\frac{\sigma_y}{\sigma_u} \le 0,7$	Permissible stress $\frac{\sigma_y}{\sigma_u} > 0,7$
Tension	σ_a	$\eta\ \sigma_y$	$\eta\ 0,41(\sigma_u + \sigma_y)$
Shear	τ_a	$\frac{\eta\ \sigma_y}{\sqrt{3}}$	$\frac{\eta\ 0,41(\sigma_u + \sigma_y)}{\sqrt{3}}$
Buckling	σ_a	σ for plating and for web plating of stiffeners $\frac{\sigma_c}{1,1}$ for stiffeners	
	τ_a	τ_c	

Symbols

σ_a = applied vertical bending stress, in N/mm^2
τ_a = applied vertical shear stress, in N/mm^2
σ_y = minimum upper yield stress of the material, in N/mm^2
σ_u = ultimate tensile strength of material, in N/mm^2
σ_c = critical buckling stress in compression, according to Pt 3, Ch 4, in N/mm^2
τ_c = critical buckling stress in shear, according to Pt 3, Ch 4, in N/mm^2
η = 0,8

10.23 Stem and stern frames

10.23.1 The stem and stern frame are to be suitably designed. The stem and stern requirements of the *Finnish-Swedish Ice Class Rules* are to be additionally considered, *see* Section 1.

10.24 Appendages

10.24.1 All appendages are to be designed to withstand forces appropriate for the location of their attachment to the hull structure or their position within a hull area.

10.25 Local details

10.25.1 Local design details are to be suitably designed to transfer ice-induced loads to supporting structure (bending moments and shear forces).

10.25.2 The loads carried by a member in way of cut-outs are not to cause instability. Where necessary, the structure is to be stiffened.

10.26 Direct calculations

10.26.1 Direct calculations are not to be utilised as an alternative to the analytical procedures prescribed in this Section.

10.26.2 Where direct calculation is used to check the strength of structural systems, the load patch specified in 10.2 is to be applied.

10.27 Welding

10.27.1 All welding within ice-strengthened areas is to be of the double continuous type.

10.27.2 Continuity of strength is to be ensured at all structural connections.

■ *Section 11*
Machinery strengthening requirements for navigation in multi-year ice conditions – Ice Classes PC1, PC2, PC3, PC4, PC5, PC6 and PC7

11.1 Application

11.1.1 The contents of this Section apply to main propulsion, steering gear, emergency and essential auxiliary systems essential for the safety of the ship and the survivability of the crew.

11.2 Drawings and particulars to be submitted

11.2.1 The following drawings and particulars to be submitted:
(a) Details of the environmental conditions and the required ice class for the machinery, if different from ship's ice class.
(b) Detailed drawings of the main propulsion machinery. Description of the main propulsion, steering, emergency and essential auxiliaries are to include operational limitations. Information on essential main propulsion load control functions.
(c) Description detailing how main, emergency and auxiliary systems are located and protected to prevent problems from freezing, ice and snow and evidence of their capability to operate in intended environmental conditions.

(d) Calculations and documentation indicating compliance with the requirements of this Section.

11.3 System design

11.3.1 Systems, subject to damage by freezing, are to be drainable.

11.3.2 Single screw vessels classed PC1 to PC5 inclusive are to have means provided to ensure sufficient vessel operation in the case of propeller damage including CP mechanism.

11.4 Materials exposed to sea water

11.4.1 Materials exposed to sea water, such as propeller blades, propeller hub and blade bolts are to have an elongation not less than 15 per cent on a test piece the length of which is five times the diameter. Charpy V impact test are to be carried out for other than bronze and austenitic steel materials. Test pieces taken from the propeller castings are to be representative of the thickest section of the blade. An average impact energy value of 20 J taken from three Charpy V tests is to be obtained at minus 10°C.

11.5 Materials exposed to sea water temperature

11.5.1 Materials exposed to sea water temperature are to be of steel or other approved ductile material. An average impact energy value of 20 J taken from three tests is to be obtained at minus 10°C.

11.6 Materials exposed to low air temperature

11.6.1 Materials of essential components exposed to low air temperature shall be of steel or other approved ductile material. An average impact energy value of 20 J taken from three Charpy V tests is to be obtained at 10°C below the lowest design temperature. *See also The Provisional Rules for the Winterisation of Ships*.

11.7 Propeller ice interaction

11.7.1 These Rules cover open and ducted type propellers situated at the stern of a vessel having controllable pitch or fixed pitch blades. Ice loads on bow propellers and pulling type propellers are to receive special consideration. The given loads are expected, single occurrence, maximum values for the whole ship's service life for normal operational conditions. These loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice. These Rules apply also for azimuthing (geared and podded) thrusters considering loads due to propeller ice interaction. However, ice loads due to ice impacts on the body of azimuthing thrusters are not covered by this Section.

11.7.2 The loads given in 11.7 are total loads (unless otherwise stated) during ice interaction and are to be applied separately (unless otherwise stated) and are intended for component strength calculations only. The different loads given here are to be applied separately.

11.7.3 F_b is a force bending a propeller blade backwards when the propeller mills an ice block while rotating ahead. F_f is a force bending a propeller blade forwards when a propeller interacts with an ice block while rotating ahead.

11.8 Ice class factors

11.8.1 Table 2.11.1 lists the design ice thickness and ice strength index to be used for estimation of the propeller ice loads.

Table 2.11.1 Propeller ice loads index

Ice Class	H_{ice}, in metres	S_{ice}	S_{qice}
PC1	4,0	1,2	1,15
PC2	3,5	1,1	1,15
PC3	3,0	1,1	1,15
PC4	2,5	1,1	1,15
PC5	2,0	1,1	1,15
PC6	1,75	1,0	1,00
PC7	1,5	1,0	1,00

where
H_{ice} = ice thickness for machinery strength design
S_{ice} = ice strength index for blade ice force
S_{qice} = ice strength index for blade ice torque

11.9 Design ice loads for open propeller

11.9.1 The maximum backward blade force, F_b, is to be taken as:
when $D < D_{limit}$

$$F_b = -27 S_{ice} (nD)^{0,7} \left(\frac{EAR}{Z}\right)^{0,3} D^2 \quad \text{kN}$$

when $D \geq D_{limit}$

$$F_b = -23 S_{ice} (nD)^{0,7} \left(\frac{EAR}{Z}\right)^{0,3} (H_{ice})^{1,4} D \quad \text{kN}$$

where
D_{limit} = $0,85 (H_{ice})^{1,4}$
n = the nominal rotational speed (at MCR free running condition) for CP-propeller and 85 per cent of the nominal rotational speed (at MCR free running condition) for a FP-propeller (regardless of driving engine type)

11.9.2 F_b is to be applied as a uniform pressure distribution to an area on the back (suction) side of the blade for the following load cases:
(a) Load case 1: from 0,6R to the tip and from the blade leading edge to a value of 0,2 chord length
(b) Load case 2: a load equal to 50 per cent of the F_b is to be applied on the propeller tip area outside of 0,9R
(c) Load case 5: for reversible propellers, a load equal to 60 per cent of the F_b is to be applied from 0,6R to the tip and from the blade trailing edge to a value of 0,2 chord length.

See load cases 1, 2, and 5 in Table 2.11.4.

11.9.3 The maximum forward blade force, F_f, is to be taken as:

when $D < D_{limit}$

$$F_f = 250 \left(\frac{EAR}{Z}\right) D^2 \quad \text{kN}$$

when $D \geq D_{limit}$

$$F_f = 500 \left(\frac{1}{1 - \frac{d}{D}}\right) H_{ice} \left(\frac{EAR}{Z}\right) D \quad \text{kN}$$

d = propeller hub diameter, in metres
D = propeller diameter, in metres
EAR = expanded blade area ratio
Z = number of propeller blades.

11.9.4 F_f is to be applied as a uniform pressure distribution to an area on the face (pressure) side of the blade for the following loads cases:

(a) Load case 3: from 0,6*R* to the tip and from the blade leading edge to a value of 0,2 chord length.
(b) Load case 4: a load equal to 50 per cent of F_f is to be applied on the propeller tip area outside of 0,9*R.*
(c) Load case 5: for reversible propellers a load equal to 60 per cent of F_f is to be applied from 0,6*R* to the tip and from the blade trailing edge to a value of 0,2 chord length.

See load cases 3, 4 and 5 in Table 2.11.4.

11.9.5 The blade spindle torque, Q_{smax}, around the spindle axis of the blade fitting is to be calculated both for the load cases described in 11.9.1 and 11.9.3 for F_h and F_f. If these spindle torque values are less than the default value given below, the default minimum value is to be used:

$$Q_{smax} = 0{,}25 F C_{0,7} \quad \text{kNm}$$

where
$C_{0,7}$ = length of the blade chord at 0,7*R* radius, in m
F = F_h or F_f whichever has the greater absolute value.

11.9.6 The maximum propeller ice torque applied to the propeller is to be taken as:

when $D < D_{limit}$

$$Q_{max} = 105 \left(1 - \frac{d}{D}\right) S_{qice} \left(\frac{P_{0,7}}{D}\right)^{0,16} \left(\frac{t_{0,7}}{D}\right)^{0,6} (nD)^{0,17} D^3 \quad \text{kNm}$$

when $D \geq D_{limit}$

$$Q_{max} = 202 \left(1 - \frac{d}{D}\right) S_{qice} H_{ice}^{1,1} \left(\frac{P_{0,7}}{D}\right)^{0,16} \left(\frac{t_{0,7}}{D}\right)^{0,6} (nD)^{0,17} D^{1,9} \quad \text{kNm}$$

where
D_{limit} = $1{,}81 H_{ice}$
S_{qice} = ice strength index for blade ice torque
$P_{0,7}$ = propeller pitch at 0,7*R*, in m
= for CP propellers, $P_{0,7}$ is to correspond to MCR in bollard condition. If not known, $P_{0,7}$ is to be taken as $0{,}7 P_{0,7n}$
$P_{0,7n}$ = propeller pitch at MCR free running condition
$t_{0,7}$ = maximum thickness at 0,7*R*
n = the rotational propeller speed, in rps, at bollard condition. If not known, n is to be taken as follows:
for CP propellers and FP propellers driven by turbine or electric motor $= n_n$
for FP propellers driven by diesel engine $= 0{,}85 n_n$
n_n = the nominal rotational speed at MCR, free running condition.

11.9.7 The maximum propeller ice thrust applied to the shaft is to be taken as:

$T_f = 1{,}1 F_f$
$T_b = 1{,}1 F_b$

11.10 Design ice loads for ducted propellers

11.10.1 The maximum backward blade force, F_b is to be taken as:

when $D < D_{limit}$

$$F_b = -9{,}5\, S_{ice} \left(\frac{EAR}{Z}\right)^{0,3} (nD)^{0,7} D^2$$

when $D \geq D_{limit}$

$$F_b = -66\, S_{ice} \left(\frac{EAR}{Z}\right)^{0,3} (nD)^{0,7} D^{0,6} (H_{ice})^{1,4}$$

where
D_{limit} = $4 H_{ice}$
n = as in 11.9.1

11.10.2 F_b is to be applied as a uniform pressure distribution to an area on the back side for the following load cases:

(a) Load case 1: on the back of the blade from 0,6*R* to the tip and from the blade leading edge to a value of 0,2 chord length
(b) Load case 5: for reversible rotation propellers a load equal to 60 per cent of F_b is applied on the blade face from 0,6*R* to the tip and from the blade trailing edge to a value of 0,2 chord length.

See load cases 1 and 5 in Table 2.11.5.

11.10.3 The maximum forward blade force, F_f, is to be taken as:

when $D \leq D_{limit}$

$$F_f = 250 \left(\frac{EAR}{Z}\right) D^2 \quad \text{kN}$$

when $D > D_{limit}$

$$F_f = 500 \left(\frac{EAR}{D}\right) D \left(\frac{1}{1 - \frac{d}{D}}\right) H_{ice} \quad \text{kN}$$

where

$$D_{limit} = \left(\frac{2}{1 - \frac{d}{D}}\right) H_{ice}$$

11.10.4 F_f is to be applied as a uniform pressure distribution to an area on the face (pressure) side for the following load cases:

(a) Load case 3: on the blade face from 0,6*R* to the tip and from the blade leading edge to a value of 0,5 chord length.
(b) Load case 5: a load equal to 60 per cent F_f is to be applied from 0,6*R* to the tip and from the blade leading edge to a value of 0,2 chord length.

See load cases 3 and 5 in Table 2.11.5.

11.10.5 The maximum propeller ice torque, Q_{max}, applied to the propeller is to be taken as:

when $D \leq D_{limit}$

$$Q_{max} = 74 \left(1 - \frac{d}{D}\right)\left(\frac{P_{0,7}}{D}\right)^{0,16}\left(\frac{t_{0,7}}{D}\right)^{0,6}(nD)^{0,17} S_{qice} D^3 \quad \text{kNm}$$

when $D > D_{limit}$

$$Q_{max} = 141 \left(1 - \frac{d}{D}\right)\left(\frac{P_{0,7}}{D}\right)^{0,16}\left(\frac{t_{0,7}}{D}\right)^{0,6}(nD)^{0,17} S_{qice} D^{1,9} H_{ice}^{1,1} \quad \text{kNm}$$

where

D_{limit} = $1,8H_{ice}$ in metres

n = the rotational propeller speed, in rps, at bollard condition. If not known, n is to be taken as follows:
for CP propellers and FP propellers driven by turbine or electric motor $= n_n$
for FP propellers driven by diesel engine $= 0,85n_n$

n_n = the nominal rotational speed at MCR at free running condition

$P_{0,7}$ = for CP propellers, propeller pitch, $P_{0,7}$ is to correspond to MCR in bollard condition. If not known, $P_{0,7}$ is to be taken as $0,7P_{0,7n}$

$P_{0,7n}$ = propeller pitch at MCR free running condition.

11.10.6 The spindle torque for CP-mechanism design, Q_{smax}, around the spindle axis of the blade fitting is to be calculated for the load case described in 11.7. If these spindle torque values are less than the default value given below, the default value is to be used:

$Q_{smax} = 0,25F\, c_{0,7}$ kNm

where

$C_{0,7}$ = the length of the blade section at $0,7R$

F = F_b or F_f whichever has the greater absolute value.

11.10.7 The maximum propeller ice thrust (applied to the shaft at the location of the propeller) is to be taken as:

$T_f = 1,1F_f$

$T_b = 1,1F_b$

11.11 Design loads on propulsion line – Torque

11.11.1 The propeller ice torque excitation for shaft line dynamic analysis is to be described by a sequence of blade impacts which are of half sine shape and occur at the blade. The torque due to a single blade ice impact as a function of the propeller rotation angle is to be taken as:

when

$\varphi = 0...\alpha_i$

$$Q(\varphi) = C_q\, Q_{max} \sin\left(\varphi \left(\frac{180}{\alpha_i}\right)\right)$$

when

$\varphi = \alpha_i...360$

$Q(\varphi) = 0$

where

C_q = as given in Table 2.11.2

α_i = as given in Table 2.11.2.

Table 2.11.2 Torque load factors

Torque excitation	Propeller-ice interaction	C_q	α_i.
Case 1	Single ice block	0,50	45
Case 2	Single ice block	0,75	90
Case 3	Single ice block	1,00	135
Case 4	Two ice blocks with 45 degree phase in rotation angle	0,50	45

11.11.2 The total ice torque is obtained by summing the torque of single blades taking into account the phase shift 360°/Z. The number of propeller revolutions during a milling sequence is to be obtained with the formula:

$N_Q = 2H_{ice}$

where

number of impacts $= Z\, N_Q$ *see* Fig. 2.11.1.

11.11.3 The milling torque sequence duration is not valid for pulling bow propellers, which are subject to special consideration. The response torque at any shaft component is to be analysed considering excitation torque $Q(\varphi)$ at the propeller, actual engine torque, Q_e, and mass elastic system. Where Q_e is the actual maximum engine torque at considered speed.

11.11.4 The design torque, Q_r, of the shaft component is to be determined by means of torsional vibration analysis of the propulsion line. Calculations are to be carried out for all excitation cases given above and the response is to be applied on top of the mean hydrodynamic torque in bollard condition at considered propeller rotational speed.

11.12 Design loads on propulsion line – Maximum response thrust

11.12.1 The maximum thrust along the propeller shaft line is to be calculated with the formulae below. The factors 2,2 and 1,5 take into account the dynamic magnification due to axial vibration. Alternatively, the propeller thrust magnification factor may be calculated by dynamic analysis.

Maximum shaft thrust forwards

$T_r = T_n + 2,2T_f$ kN

Maximum shaft thrust backwards

$T_r = 1,5T_b$ kN

where

T_n = hydrodynamic propeller bollard thrust, in kN. If not known, T_n is to be as given in Table 2.11.3

T_f = maximum forward propeller ice thrust, in kN.

Table 2.11.3 Propeller thrust factor

Propeller type	T_n
CP propellers (open)	1,25T
CP propellers (ducted)	1,10T
FP propellers driven by turbine or electric motor	T
FP propellers driven by diesel engine (open)	0,85T
FP propellers driven by diesel engine (ducted)	0,75T
Symbols	
T = nominal propeller thrust at MCR at free running open water conditions	

Table 2.11.4 Load cases for open propeller

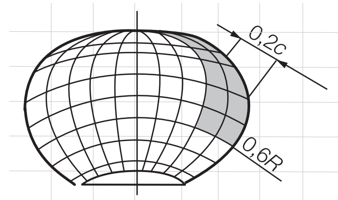
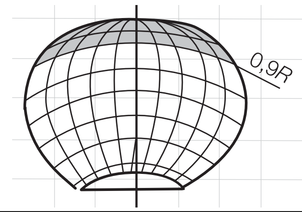
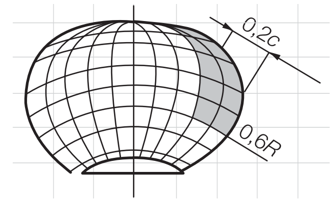
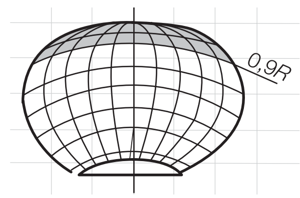
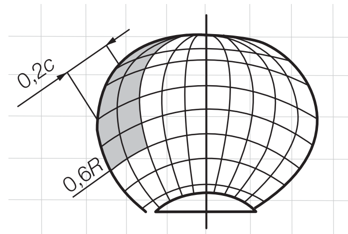
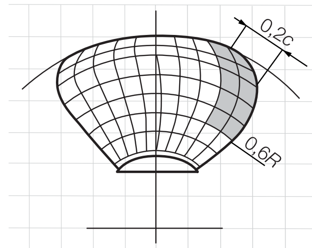
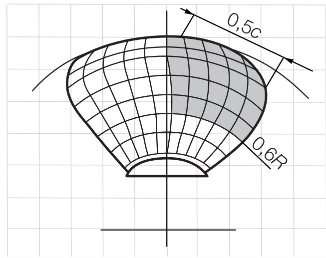
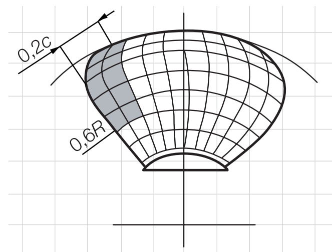
Load case	Force	Loaded area	Right handed propeller blade seen from back
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0,6R to the tip and from the leading edge to 0,2 times the chord length.	
Load case 2	50% of F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside of 0,9R radius.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0,6R to the tip and from the leading edge to 0,2 times the chord length.	
Load case 4	50% of F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside of 0,9R radius.	
Load case 5	60% of F_f or F_b whichever is the greater	Uniform pressure applied on propeller face (pressure side) to an area from 0,6R to the tip and from the trailing edge to 0,2 times the chord length.	

Table 2.11.5 Load cases for ducted propeller

Load case	Force	Loaded area	Right handed propeller blade seen from back
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0,6*R* to the tip and from the leading edge to 0,2 times the chord length	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0,6*R* to the tip and from the leading edge to 0,5 times the chord length	
Load case 5	60% of F_f or F_b	Uniform pressure applied on propeller face (pressure side) to an area from 0,6*R* to the tip and from the trailing edge to 0,2 times the chord length	

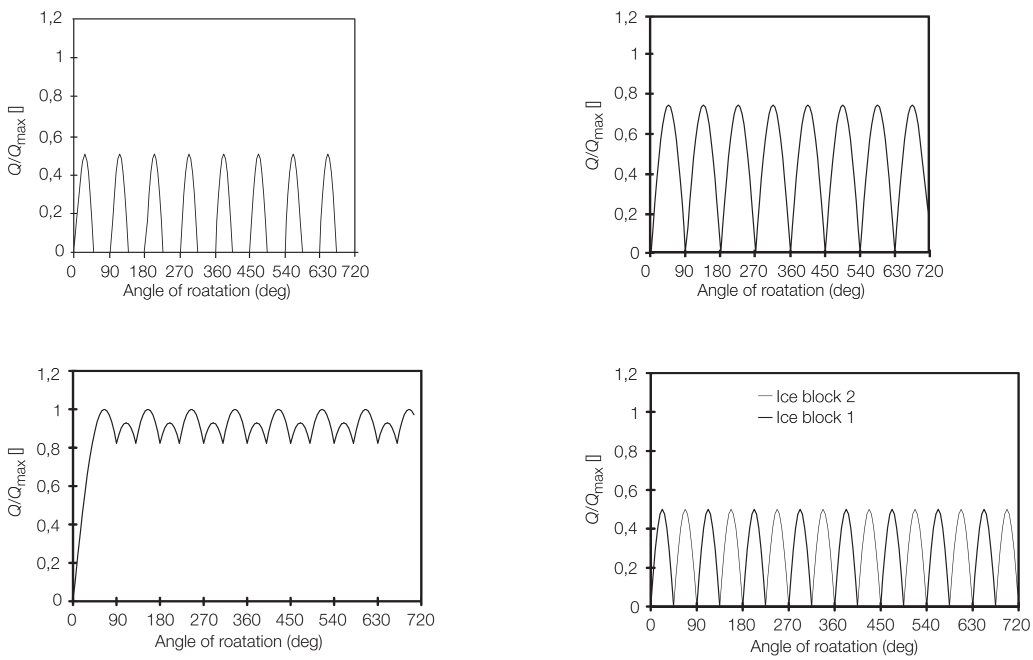


Fig. 2.11.1
The shape of the propeller ice torque excitation for 45, 90, 135 degrees single blade impact sequences and 45 degrees double blade impact sequence (two ice pieces) on a four bladed propeller

11.13 Design loads on propulsion line – Blade failure load for both open and nozzle propellers

11.13.1 The force is acting at 0,8R in the weakest direction of the blade and at a spindle arm of 2/3 of the distance of axis of blade rotation of leading and trailing edge whichever is the greatest. The blade failure load is to be taken as:

$$F_{ex} = \frac{0{,}3c\, t^2\, \sigma_{ref}}{0{,}8D - 2r} \times 10^{-3} \quad \text{kN}$$

where

σ_{ref} = $0{,}6\sigma_{0,2} + 0{,}4\sigma_u$

$\sigma_{0,2}$ and σ_u = representative values for the blade material

c, t and r = the actual chord length, thickness and radius of the cylindrical root section of the blade at the weakest section outside root fillet and typically will be at the termination of the fillet into the blade profile

11.14 Design – Design principle

11.14.1 The strength of the propulsion line is to be designed:

(a) for maximum loads in 11.7;

(b) such that the plastic bending of a propeller blade will not cause damage in other propulsion line components;

(c) with sufficient fatigue strength.

11.15 Design – Azimuthing main propulsors

11.15.1 In addition to the above requirements, special consideration will be given to the loading cases which are extraordinary for propulsion units when compared with conventional propellers. Estimation of the loading cases must reflect the operational realities of the ship and the thrusters. In this respect, for example, the loads caused by impacts of ice blocks on the propeller hub of a pulling propeller are to be considered. Also, loads due to thrusters operating in an oblique angle to the flow are to be considered. The steering mechanism, the fitting of the unit and the body of the thruster is to be designed to withstand the loss of a blade without damage. The plastic bending of a blade is to be considered in the propeller blade position, which causes the maximum load on the studied component.

11.15.2 Azimuth thrusters are also to be designed for estimated loads due to thruster body/ice interaction as in 10.24.

11.16 Blade design – Maximum blade stresses

11.16.1 Blade stresses are to be calculated using the backward and forward loads given in sub-Sections 11.9 and 11.10. The stresses are to be calculated with recognised and well documented FE-analysis or another acceptable alternative method. The stresses on the blade are not to exceed the allowable stresses, σ_{all}, for the blade material given below. The calculated blade stress for the maximum ice load is to comply with the following:

$$\sigma_{calc} < \sigma_{all} = \frac{\sigma_{ref}}{S}$$

where

S = 1,5

σ_{ref} = reference stress, defined as:
$0{,}7\sigma_u$
$0{,}6\,\sigma_{0,2} + 0{,}4\sigma_u$ whichever is less

σ_u and $\sigma_{0,2}$ = representative values for the blade material.

11.17 Blade design – Blade edge thickness

11.17.1 The blade edge thicknesses, t_{ed}, and tip thickness t_{tip}, are to be greater than t_{edge} given by the following formula:

$$t_{edge} \geq x\, S\, S_{ice} \sqrt{\frac{3P_{ice}}{\sigma_{ref}}}$$

where

x = distance from the blade edge measured along the cylindrical sections from the edge and is to be 2,5 per cent of chord length, however not to be taken greater than 45 mm.
In the tip area (above 0,975R radius) x is to be taken as 2,5 per cent of 0,975R section length and is to be measured perpendicularly to the edge, however not to be taken greater than 45 mm.

S = safety factor
= 2,5 for trailing edges
= 3,5 for leading edges
= 5,0 for tip

S_{ice} = as given in 11.8

p_{ice} = ice pressure
= 16 MPa for leading edge and tip thickness

σ_{ref} = as given in 11.16.

11.17.2 The requirement for edge thickness is to be applied for leading edge and in case of reversible rotation open propellers also for the trailing edge. Tip thickness refers to the maximum measured thickness in the tip area above 0,975R radius. The edge thickness in the area between the position of maximum tip thickness and edge thickness at 0,975 radius has to be interpolated between edge and tip thickness value and smoothly distributed.

11.18 Prime movers

11.18.1 The main engine is to be capable of being started and running the propeller with the CP in full pitch.

11.18.2 Provisions are to be made for heating arrangements to ensure ready starting of the cold emergency power units at an ambient temperature applicable to the Polar class of the ship.

11.18.3 Emergency power units are to be equipped with starting devices with a stored energy capability of at least three consecutive starts at the design temperature in 11.18.2. The source of stored energy is to be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. A second source of energy is to be provided for an additional three starts within 30 min., unless manual starting can be demonstrated to be effective.

11.19 Machinery fastening loading accelerations

11.19.1 Essential equipment and main propulsion machinery supports are to be suitable for the accelerations as indicated in the following. Accelerations are to be considered acting independently.

11.19.2 The maximum longitudinal impact acceleration, a_l, at any point along the hull girder is to be taken as:

$$a_l = \left(\frac{F_{IB}}{\Delta}\right)\left\{[1,1 \tan(\gamma + \phi)] + \frac{7H}{L}\right\} \quad \text{m/s}^2$$

where

F_{IB} = vertical impact force, defined in 10.19
H = distance from the waterline to the point being considered, in metres
L = length between perpendiculars, in metres
ϕ = maximum friction angle between steel and ice, normally taken as 10, in degrees
γ = bow stem angle at waterline, in degrees
Δ = Displacement.

11.19.3 The combined vertical impact acceleration, a_v, at any point along the hull girder, is to be taken as:

$$a_v = 2,5\left(\frac{F_{IB}}{\Delta}\right)F_x \quad \text{m/s}^2$$

where

F_X = 1,3 at the FP
= 0,2 at midships
= 0,4 at the AP
= 1,3 at the AP for vessels conducting icebreaking astern
= intermediate values are to be determined by linear interpolation.

11.19.4 The combined transverse impact acceleration, a_t, at any point along hull girder, is to be taken as:

$$a_t = 3F_i\left(\frac{F_x}{\Delta}\right) \quad \text{m/s}^2$$

where

F_X = 1,5 at the FP
= 0,25 at midships
= 0,5 at the AP
= 1,5 at the AP for vessels conducting icebreaking astern
= intermediate values are to be determined by linear interpolation
F_i = total force normal to shell plating in the bow area due to oblique ice impact, defined in 10.19.

11.20 Auxiliary systems

11.20.1 Machinery is to be protected from the harmful effects of ingestion or accumulation of ice or snow. Where continuous operation is necessary, means are to be provided to purge the system of accumulated ice or snow.

11.20.2 Means are to be provided to prevent damage due to freezing, to tanks containing liquids.

11.20.3 Vent pipes, intake and discharge pipes and associated systems are to be designed to prevent blockage due to freezing or ice and snow accumulation.

11.21 Sea inlets and cooling water systems

11.21.1 Cooling water systems for machinery that are essential for the propulsion and safety of the vessel, including sea chest inlets, are to be designed for the environmental conditions applicable to the ice class.

11.21.2 At least two sea chests are to be arranged as ice boxes for classes PC1 to PC5 inclusive. The calculated volume for each of the ice boxes is to be at least 1 m^3 for every 750 kW of the total installed power. For PC6 and PC7, there is to be at least one ice box located preferably near centreline.

11.21.3 Ice boxes are to be designed for an effective separation of ice and venting of air.

11.21.4 Sea inlet valves are to be secured directly to the ice boxes. The valves are to be a full bore type.

11.21.5 Ice boxes and sea bays are to have vent pipes and are to have shut off valves connected directly to the shell.

11.21.6 Means are to be provided to prevent freezing of sea bays, ice boxes, ship side valves and fittings above the load waterline.

11.21.7 Efficient means are to be provided to re-circulate cooling seawater to the ice box. The total sectional area of the circulating pipes is not to be less than the area of the cooling water discharge pipe.

11.21.8 Detachable gratings or manholes are to be provided for ice boxes. Manholes are to be located above the deepest load line. Access is to be provided to the ice box from above.

11.21.9 Openings in ship sides for ice boxes are to be fitted with gratings, or holes or slots in shell plates. The net area through these openings is to be not less than 5 times the area of the inlet pipe. The diameter of holes and width of slot in shell plating is to be not less than 20 mm. Gratings of the ice boxes are to be provided with a means of clearing. Clearing pipes are to be provided with screw-down type non-return valves.

11.22 Ballast tanks

11.22.1 Efficient means are to be provided to prevent freezing in fore and after peak tanks and wing tanks located above the waterline and where otherwise found necessary. *See* 2.1.3 and *The Provisional Rules for the Winterisation of Ships*, 3.2.1.

11.23 Ventilation system

11.23.1 The air intakes for machinery and accommodation ventilation are to be located on both sides of the ship.

11.23.2 Accommodation and ventilation air intakes are to be provided with means of heating.

11.23.3 The temperature of the inlet air provided to machinery from the air intakes is to be suitable for the safe operation of the machinery.

11.24 Alternative design

11.24.1 As an alternative a comprehensive design study may be submitted and may be requested to be validated by an agreed test programme.

Cross-references

Section numbering in brackets reflects any Section re-numbering necessitated by any of the Notices that update the current version of the Rules for Ships.

Part 1, Chapter 3

17.2.5	Reference to Pt 5, Ch 23,6.3.7 *now reads* Pt 5, Ch 9,6.3.7.

Part 3, Chapter 4

8.2.4(e)	Reference to Ch 3,13.2 *now reads* Ch 3,9.2.

Part 3, Chapter 5

4.1.5	Reference to Ch 9,12 *now reads* Ch 9,8.
5.1.4	Reference to Ch 9,13 *now reads* Ch 9,9.

Part 3, Chapter 6

4.1.5	Reference to Ch 9,13 *now reads* Ch 9,9.
5.1.3	Reference to Pt 3, Ch 9,13 *now reads* Ch 9,9.

Part 3, Chapter 9

10.3.1 ***(6.3.1)***	Reference to 10.3.2 *now reads* 6.3.2. Reference to 10.3.3 *now reads* 6.3.3.
10.4.1 ***(6.4.1)***	Reference to Table 9.10.1 *now reads* Table 9.6.1.
12.1.1 ***(8.1.1)***	Reference to Table 9.12.1 *now reads* Table 9.8.1.
13.1.3 ***(9.1.3)***	Reference to 13.2.1 *now reads* 9.2.1.
13.3.1 ***(9.3.1)***	Reference to 13.2.1 *now reads* 9.2.1.
13.4.1 ***(9.4.1)***	Reference to 13.2.1 *now reads* 9.2.1.

Part 4, Chapter 1

5.1.2	Reference to Pt 3, Ch 9,13 *now reads* Pt 3, Ch 9,9.
6.1.5	Reference to Pt 3, Ch 9,13 *now reads* Pt 3, Ch 9,9.
7.1.4	Reference to Pt 3, Ch 9,13 *now reads* Pt 3, Ch 9,9.
8.2.6	Reference to Pt 3, Ch 9,13 *now reads* Pt 3, Ch 9,9.

Part 4, Chapter 5

6.1.1	Reference to Pt 3, Ch 9,13 *now reads* Pt 3, Ch 9,9.

Part 4, Chapter 7

2.2.3	Reference to Pt 3, Ch 9,13 *now reads* Pt 3, Ch 9,9.
Table 7.8.1	Reference to Pt 3, Ch 9,13 *now reads* Pt 3, Ch 9,9.
9.2.2	Reference to Pt 3, Ch 9,13 *now reads* Pt 3, Ch 9,9.

Part 4, Chapter 9

9.3.8	Reference to Pt 3, Ch 9,13 *now reads* Pt 3, Ch 9,9.

Part 4, Chapter 10

1.1.2	Reference to Pt 3, Ch 9,13 *now reads* Pt 3, Ch 9,9.

Part 5, Chapter 9

This Chapter was previously Part 5, Chapter 23

1.1.4	Reference to Fig. 23.1.1 *now reads* Fig. 9.1.1.
2.2.1(e)	Reference to Fig. 23.2.1 *now reads* Fig. 9.2.1.
2.4.1	Reference to Fig. 23.2.1 *now reads* Fig. 9.2.1.
5.1.7	References to Table 23.5.1 *now read* Table 9.5.1.
5.2.3	Reference to Fig. 23.5.1 *now reads* Fig. 9.5.1.
5.2.4	Reference to Table 23.5.2 *now reads* Table 9.5.2.
5.2.5	Reference to Fig. 23.5.1 *now reads* Fig. 9.5.1.
5.2.6	Reference to Table 23.5.2 *now reads* Table 9.5.2.
5.3.4	Reference to Table 23.5.2 *now reads* Table 9.5.2.
5.3.5	Reference to Table 23.5.2 *now reads* Table 9.5.2.
6.3.7	Reference to Fig. 23.2.1 *now reads* Fig. 9.2.1.
8.2.1	Reference to Table 23.8.1 *now reads* Table 9.8.1.
8.2.2	Reference to Table 23.8.1 *now reads* Table 9.8.1.

Part 5, Chapter 23

This Chapter has been moved to Part 5, Chapter 9.

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